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QUESTIONS

ON SUBJECTS CONNECTED WITH THE

MARINE STEAM-ENGINE,

AND

EXAMINATION PAPERS,

WITH HINTS FOR THEIR SOLUTION.

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QUESTIONS ON SUBJECTS

CONNECTED WITH

THE STEAM-ENGINE.

1. FIND the circumference of a valve whose diameter is $3\frac{1}{2}$ inches.

$$\begin{aligned}\text{Since circumference} &= 3\cdot1416 \times \text{diameter}\\ &= 3\cdot1416 \times 3\cdot5\\ &= 10\cdot9956. \quad \textit{Ans.}\end{aligned}$$

2. Find the length of the outer ring of a paddle-wheel of H.M.S. *Gorgon*, whose diameter is 26 feet.

Ans. 81·6816 feet.

3. Find the circle described by the outer edge of the screw of H.M.S. *Wellington*, the diameter being 18 feet.

Ans. 56·5483 feet.

4. The circumference of a circle being 50 feet; find the diameter.

$$\begin{aligned}\text{Since diameter} &= \frac{\text{circumference}}{3\cdot1416}\\ &= \frac{50}{3\cdot1416}\\ &= 15\cdot912 \text{ feet.} \quad \textit{Ans.}\end{aligned}$$

5. The circumference of the piston of H.M.S. *Terrible* is 226·1952 inches; find the diameter. *Ans.* 72 inches.

6. The circumference of the piston-rod of H.M.S. *Penelope* is 28·2 inches; find its diameter. *Ans.* 8·9 inches.

7. Find the area of a circle whose diameter is 15 inches.

Since area = ·7854 × (diameter)^2

and $15^2 = 225$

$\therefore$ area = ·7854 × 225 = 176·715. *Ans.*

8. How many square inches are there in both pistons of double-cylinder engines of H.M.S. *Terrible*, the diameter being 72 inches? *Ans.* 8143·03 inches.

9. Find the pressure on the pistons of each engine of H.M.S. *Terrible*, if the force of the steam be 8 lbs. per inch, supposing the atmosphere to be acting on the opposite side of the piston.

Ans. 29 tons, nearly.

10. Find the area of an air-pump bucket which is $\frac{1}{5}$ that of the cylinder, the diameter of the cylinder being 63 inches.

Ans. 623·45 square inches.

11. What is the diameter of a piston containing 4809 square inches?

Area = ·7854 × (diameter)^2

$$\therefore \text{diameter} = \sqrt{\frac{\text{area}}{\cdot 7854}}$$

$$= \sqrt{\frac{4809}{\cdot 7854}} = \sqrt{6122 \cdot 99}$$

= 78·2 inches nearly. *Ans.*

12. What is the diameter of a valve containing 100 square inches? *Ans.* 11·28 square inches.

13. What is the diameter of a valve containing 227 square inches? *Ans.* 17 inches nearly.

14. Find the diameter of a circle containing 20 square inches. *Ans.* 5·04 inches.

15. The area of a piston is 4536 square inches; find the diameter of the piston-rod, which is $\frac{1}{8}$ that of the piston.

Ans. $9\frac{1}{2}$ inches.

16. The area of a piston is 3318 square inches, and the diameter of the piston-rod is $\frac{1}{8}$ that of the piston; find it.

Ans. 8·125 inches.

17. The diameter of a piston-rod is 4 inches, and that of the piston 33 inches; compare the area of a section of the rod with the area of the piston.

Since the areas of circles are as the squares of their diameters, their areas will be as $4^2 : 33^2$;

or, as 16 : 1089;

or, as 1 : 68·06 nearly. *Ans.*

18. The diameters of rod and piston are 3·1 and 25 inches respectively; compare their areas. *Ans.* As 1 : 65 nearly.

19. The diameters of a piston-rod and piston are $3\frac{1}{2}$ inches and $28\frac{1}{2}$ inches respectively; compare their areas.

Ans. As 1 : 66·3 nearly.

20. Find the *effective* areas of the upper and lower sides of a steam-piston, whose diameter is 63 inches, the diameter of the piston-rod being 6·4 inches.

Ans. 3085·08 and 3117·25 square inches.

21. If the diameter of a cylinder be 60 inches, and the piston-rod be $\frac{1}{10}$ the piston in diameter; find the pressure of the steam on the upper and lower sides of the piston when acted on by steam of 10 lbs.—

(1) If the atmosphere act to oppose the steam;

(2) If there be no resistance to motion.

Ans. In the first case, 27,991 lbs. and 28,274 lbs.;
in the second case, 69,973 lbs. and 70,686 lbs.

NOTE. In this problem we have neglected the effect of the atmosphere on the end of the piston-rod; the effect of which will be shown in the next problem.

22. If p_1 and p_2 be the pressure of the steam, and of the condensed vapour, on the opposite sides of a steam-piston whose area is A; and if p be the atmospheric pressure acting at the

end of the piston-rod, whose area is B; find the whole effective force in the up and down strokes respectively:—

(1) In the up-stroke:

Pressure on under side is $p_1 A$,
and resisting pressure of vapour on upper side is $p_2(A-B)$;
also pressure of atmosphere on piston-rod is pB,
$\therefore$ total resisting pressure is $p_2(A-B)+pB$,
and the total *effective* pressure is $p_1A-p_2(A-B)-pB$,
$=(p_1-p_2)A+(p_2-p)B$.

(2) In the down-stroke:

The downward pressure of steam is $p_1(A-B)$,
and pressure of atmosphere is pB,
$\therefore$ the total downward pressure is $p_1(A-B)+pB$;
also resisting pressure of vapour is p_2A,
$\therefore$ the total effective downward force $=p_1A-p_1B+pB-p_2A$,
$=(p_1-p_2)A-(p_1-p)B$,
$=(p_1-p_2)A+(p-p_1)B$.

23. Having given the pressure of the atmosphere and that of the uncondensed vapour; find whether the effective force in the up or down stroke is the greater.

Force in up-stroke $=(p_1-p_2)A+(p_2-p)B$,
and ditto in down-stroke $=(p_1-p_2)A+(p-p_1)B$;
$\therefore$ the upward force is greater than the downward
if $(p_1-p_2)A+(p_2-p)B>(p_1-p_2)A+(p-p_1)B$;
or if $(p_2-p)B>(p-p_1)B$;
or if $p_2-p>p-p_1$;
or if $p_1+p_2>2p$;
or if $\frac{p_1+p_2}{2}>p$;

and *vice versa*, the force in the down-stroke is greater than that in the up-stroke if $p>\frac{p_1+p_2}{2}$.

Hence, in most cases, with condensing engines the descending stroke is more effective than the ascending stroke, which is the converse of what would at first sight be supposed.

24. The pressure of steam is 10 lbs. per inch, and that of the uncondensed vapour 2 lbs.; is the force greater in the up or down stroke?

Here $15-2=13$ lbs.;

and, since 10 is less than 13, the force of the down-stroke is greater than that of the up-stroke.

25. The pressure of steam is 20 lbs., and that of the condensed vapour 2 lbs.; is the force greater in the up-stroke?

Ans. The force in the up-stroke is the greater.

26. Find the area of an annular valve whose greater and lesser diameters are 12 and 9 inches respectively.

Area of whole circle $= \cdot 7854 \times 12^2 = 113 \cdot 0976$.
Area of lesser circle $= \cdot 7854 \times 9^2 = 63 \cdot 6174$.
$\therefore$ area of annulus $= 49 \cdot 4802$ square inches.

27. What is the area of an annular valve whose greater and lesser diameters are 8 and 4 inches respectively?

Ans. $37 \cdot 7$ square inches.

28. Find the area of a ring whose diameter is 70 inches, and breadth 2 inches. *Ans.* $427 \cdot 26$ square inches.

29. The steam-pressure on a piston is 20 tons, and the total pressure per square inch is 30 lbs. Find its diameter.

Since 20 tons $= 20 \times 2240$ lbs. $= 44800$ lbs.,

and $\frac{44800}{30} = \frac{4480}{3}$ square inches in the area of the piston;

let $\therefore x =$ diameter of piston;

then $\cdot 7854 \times x^2 = \frac{4480}{3} = 1493 \cdot 3333$;

$\therefore x^2 = 1901 \cdot 37$ square inches,

and $x = 43 \cdot 6$ inches. *Ans.*

30. The total steam-pressure on 4 equal pistons is 100 tons, being 20 lbs. per square inch; find their diameters.

Ans. $59 \cdot 7$ inches.

31. The total pressure on a pair of equal pistons is 90 tons, at the rate of 45 lbs. on each square inch; find their diameters.

Ans. $53 \cdot 4$ inches.

32. A single-cylinder engine is to be substituted for a double-cylinder engine, whose pistons are 40 inches in diameter; if the

speed of the pistons and the horse-power remain the same, find the diameter of the former.

Let x = the diameter;
then $\cdot 7854 \times x^2$ = area;
again, $\cdot 7854 \times 40^2$ = area of each piston of latter engine;
$\therefore \cdot 7854 \times x^2 = 2 \times \cdot 7854 \times 40^2$,
or $x^2 = 2 \times 40^2$,
$= 3200$,
and $x = 56 \cdot 5$ inches. *Ans.*

33. A pair of single cylinders is to be substituted for a pair of double cylinders; the engines are to work at the same speed, and be of the same horse-power: if the diameter of the latter be 60 inches, find that of the former. *Ans.* 84·8 inches.

34. The diameter of a steam cylinder being 64 inches, what must be the diameters of the cylinders of a double-cylinder engine, of the same power and speed, to supply its place?

Ans. 45·25 inches.

35. The diameter of a valve is 10 inches; find the number of square inches, and the number of circular inches in it.

Ans. 78·54 square inches,
and 100 circular inches.

36. How many circular inches are there in a piston of 33 inches diameter? *Ans.* 1089 circular inches.

37. A rivet-hole is half an inch in diameter; express its area in circular inches. *Ans.* ·25 circular inches.

38. If a valve contain 55 square inches; how many circular inches does it contain?

$\frac{55}{\cdot 7854} = 70$ circular inches, nearly.

39. A valve contains 100 square inches; how many circular inches does it contain? *Ans.* 127·3.

40. In 201 square inches, how many circular inches?

Ans. 256.

41. If the pressure on a valve be 15 lbs. on each square inch, what is the pressure on the circular inch?

Here $15 \times \cdot 7854 = 11 \cdot 78$ lbs.

42. If the pressure on a valve be 10 lbs. on each square inch, what is the pressure on each circular inch?

Ans. $7 \cdot 854$ lbs.

43. Suppose a safety-valve to be loaded to 5 lbs. on each square inch, how much is that on each circular inch?

Ans. $3 \cdot 927$ lbs.

44. A valve is 6 inches in diameter; show that the pressure on it is $141 \cdot 372$ lbs., whether it be considered to be loaded to 5 lbs. per square inch, or $3 \cdot 927$ lbs. per circular inch.

45. Find the rounded surface of a cylindrical vessel whose diameter is 20 inches and height 14 inches.

(1) Circumference of base $= 3 \cdot 1416 \times 20$
$= 62 \cdot 832.$

(2) Surface required = circumference and height
$= 62 \cdot 832 \times 14$
$= 879 \cdot 648$ square inches.

46. The diameter of a cylinder is 54 inches, and height 4 feet 4 inches; what is the area of the rounded surface?

Ans. $61 \cdot 26$ square feet.

47. How many square feet of felt will be required to coat a cylinder, whose diameter is 66 inches and height 5 feet 3 inches?

Ans. $90 \cdot 71$ square feet.

48. In a cylindrical coal-measure, the area of the rounded surface is equal to the base; prove that its height is equal to $\frac{1}{4}$ the diameter of the base.

49. Having 250 square inches of sheet-tin to make the rounded surface of a cylindrical vessel; find the diameter, the height being 9 inches. *Ans.* $8 \cdot 84$ inches.

50. A manufacturer has half a cubic foot of brass, which he wishes to make into a hollow cylinder closed at both ends; the

thickness of the metal is to be $\frac{1}{4}$ inch, and the diameter 2 feet 9 inches; find the height of the cylinder.

Ans. 1 foot 4·845 inches.

51. Find the area of rubbing-surface in a steam cylinder $91\frac{1}{2}$ inches in diameter, the stroke of the piston being 6 feet 8 inches.

Ans. 159·6 square feet.

52. Find the contents of a cylinder whose diameter is 20 inches and height 14 inches.

Area of base $= \cdot 7854 \times 400 = 314 \cdot 16$ square inches.

Contents of cylinder $= 314 \cdot 16 \times 14 = 4398 \cdot 24$ cubic inches.

53. Find the contents of the *Bee's* cylinder, whose diameter is 20 inches, and length of stroke is 2 feet, neglecting the thickness of piston and clearance. *Ans.* 7539·84 cubic inches.

54. Find in the above cylinder the space for steam on each side of the piston, allowing $\frac{1}{2}$ inch for clearance at each end.

Ans. 7696·92 cubic inches.

55. Find the whole content of the same cylinder after the piston, whose thickness is 6 inches, has been removed.

Ans. 9738·96 cubic inches.

56. Find the volume of a steam cylinder 70 inches in diameter and 6 feet high. *Ans.* 160·3 cubic feet.

57. Find the volume and weight of a brass cylinder, whose diameter is 12 inches, and height 10 inches; a cubic foot of brass weighing 525 lbs.

Volume $= 1130 \cdot 976$ cubic inches.

And hence weight $= \frac{1130 \cdot 976}{1728} \times 525$ lbs. $= 343$ lbs. 10 oz. *Ans.*

58. What weight of water will be raised at each stroke of an air-pump, whose diameter is 35 inches, and stroke 2 feet 9 inches, the pump being one-third full at each stroke?

Ans. 391·97 lbs.

(A cubic foot of salt-water weighs 64 lbs.)

59. How many tons of salt-water will be raised in an hour by the air-pumps of a pair of engines, whose diameters are 31 inches each, length of stroke 2 feet 6 inches, and number of strokes per minute 36, the pump being one-third full at each stroke? *Ans.* 539 tons.

60. What weight of water will be discharged per hour by the air-pumps of two engines, the diameters of whose buckets are 2 feet 6 inches, and length of stroke 3 feet, number of strokes per minute being 16, and the pumps one-third full at each stroke? *Ans.* 269·25 tons.

61. The air-pump of H.M.S. *Bee* delivers 14 tons of water in an hour, the bucket is 10 inches in diameter, and the number of strokes 40; what is the height of the water in the pump at each stroke? *Ans.* 4·49 inches.

62. What is the content of a cone, whose height is 15 inches and diameter of base 12 inches?

$$\cdot 7854 \times 12^2 = 113 \cdot 0976$$

and $\frac{113 \cdot 0976 \times 15}{3} = 565 \cdot 48$ cubic inches. *Ans.*

63. What is the weight of an iron cone, the diameter of the base being 7 inches, and height 10 inches? weight of a cubic foot of iron being 441 lbs. *Ans.* 32·74 lbs.

64. The weight of a cubic foot of lead is 717 lbs.; find the weight of a leaden cone, whose height is one foot, and diameter of base 10 inches. *Ans.* 130·4 lbs.

65. The area of the base of a cone is 450 square inches; what must be its height that its volume may be a cubic foot?

Ans. 11·5 inches.

66. The height of a cone is 12 inches; what must be the diameter of the base that the volume may be a cubic foot?

Ans. 23·45 inches.

67. Find the area of an oval man-hole door, whose greater and lesser diameters are 2 feet 6 inches and 1 foot 9 inches.

2 feet 6 inches = 30 inches
1 foot 9 inches = 21 inches
$\therefore$ area $= \cdot 7854 \times 30 \times 21$
$= 494 \cdot 8$ square inches. *Ans.*

68. The greater and lesser diameters of an oval man-hole door are 2 feet 9 inches and 2 feet 6 inches; find its area.

Ans. $777 \cdot 7$ square inches.

69. What is the area of an oval door, whose dimensions are 12 inches by 9 inches? *Ans.* $84 \cdot 82$ square inches.

70. Find approximately the periphery of the ovals mentioned in the last three questions.

Ans. $80 \cdot 11$ inches, 98 inches, and 33 inches.

71. Find the surface of an oval cylinder, whose diameters are 34 inches and 30 inches, and height 24 inches.

The mean diameter is 32 inches
and $\therefore$ periphery $= 3 \cdot 1416 \times 32$
$= 100 \cdot 53$ inches nearly
also $100 \cdot 53 \times 24 = 2412 \cdot 72$ square inches
$= 16 \cdot 75$ square feet. *Ans.*

72. The greater diameter of an oval funnel is 4 feet 6 inches, and the lesser diameter 4 feet; what space will it occupy on the deck, and how many square feet of iron does it contain if its height be 16 feet? *Ans.* Area, 14 square feet nearly, and surface, 214 square feet.

73. Find the pressure on a blow-valve 4 inches in diameter, the steam-gauge standing at 7 inches, and the condenser-gauge at 26 inches.

Area of valve $= 12 \cdot 56$ square inches
and press. of steam $= 7 + 15 = 22$ lbs. per square inch,
also press. in condenser $= 2$ lbs.

Hence net pressure per square inch

$$= 22 - 2 = 20 \text{ lbs.}$$

and total pressure on valve

$$= 12 \cdot 56 \times 20 = 251 \cdot 2 \text{ lbs.}$$

74. Find the pressure on a blow-valve, whose diameter is 6 inches, the steam-gauge standing at 10 lbs., and the condenser-gauge at 28 inches. *Ans.* 678·58 lbs.

75. Required the force to lift a blow-valve when the boiler-gauge stands at 8 and the condenser-gauge at 26 inches, the diameter of the valve being $5\frac{1}{2}$ inches. *Ans.* 498·93 lbs.

76. Find the power that must be exerted to open a blow-valve 5 inches in diameter, when the boiler-gauge stands at 10 inches, and the condenser-gauge at 28 inches.

Ans. 471·24 lbs.

77. What pressure is acting on a snifting-valve 6 inches in diameter, when the condenser-gauge stands at 26 inches?

Press. on square inch of upper side = 15 lbs.

Do. do. lower side = 2 lbs.

Hence net pressure per square inch = 13 lbs.

and area of valve $= \cdot 7854 \times 36$

$= 28 \cdot 2744$ square inches.

$\therefore$ total pressure $= 28 \cdot 2744 \times 13$

$= 367 \cdot 57$ lbs. *Ans.*

78. Find the pressure on a snifting-valve 4 inches in diameter, when the condenser-gauge stands at 28 inches.

Ans. 175·9 lbs.

79. What force must be used to lift a snifting-valve 7 inches in diameter, when the condenser-gauge stands at 25 inches?

Ans. 481 lbs.

80. The diameter of a snifting-valve is $8\frac{1}{2}$ inches; what is the pressure on it to keep it close, the condenser-gauge standing at 27 inches? *Ans.* 766 lbs.

81. If the snifting-valve of an engine do not fit close, what

will be the pressure on the foot-valve of the air-pump, its dimensions being 2 feet by 15 inches, and the condenser-gauge at 20 inches? *Ans.* 3600 lbs.

82. Find the internal surface of a steam-cylinder whose diameter is 92 inches, and length 7 feet; and find how much the external exceeds the internal surface, supposing the thickness of the iron to be $1\frac{1}{2}$ inches.

(1) $\frac{92\times3\cdot1416\times7\times12}{144}=168\cdot58$ square feet.

(2) $92+1\cdot5\times2=95$.

And $\frac{95\times3\cdot1416\times7\times12}{144}=174\cdot09$ square feet;

also, $174\cdot09-168\cdot58=5\cdot51$ square feet in excess.

83. Find the excess of the outer over the inner surface of a steam-cylinder, the diameter of the piston being 95 inches, the length of stroke 7 feet 6 inches, clearance at each end $\frac{1}{2}$ inch, and thickness of iron 3 inches. *Ans.* $11\cdot9$ square feet.

84. The inner diameter of a cylinder is 60 inches, and outer diameter $62\cdot5$ inches; the length is 5 feet 4 inches; find the internal and external surfaces.

Ans. $83\cdot77$ and $87\cdot27$ square feet.

85. The lap on the steam-side of the upper slide-face of an engine is $3\frac{1}{4}$ inches, and that on the lower face is $3\frac{3}{8}$ inches, the maximum opening for steam at each port is $3\frac{3}{8}$ inches; find the travel of the slide.

When the slide is at the middle of its stroke it must rise $3\frac{1}{4}$ inches before the port begins to admit steam, and $3\frac{3}{8}$ inches more before it is fully open: hence the whole rise of the slide above the mean position is $3\frac{1}{4}+3\frac{3}{8}$ inches$=6\frac{5}{8}$ inches.

Similarly, the whole descent of the slide below that position is

$$3\tfrac{3}{8}+3\tfrac{3}{8}=6\tfrac{3}{4}\text{ inches};$$

$\therefore$ the whole travel $=6\frac{5}{8}+6\frac{3}{4}=13\frac{3}{8}$ inches.

86. The steam-lap on the *upper* slide-face of an engine is 2 inches, and on the *lower* face $1\frac{1}{2}$ inches, the maximum opening

for steam at the upper and lower ports respectively are 2 inches and $2\frac{1}{2}$ inches; find the whole travel of the slide.

Ans. 8 inches.

87. A slide has $3\frac{1}{2}$ inches lap on the steam-side of the upper port, and $\frac{1}{4}$ inch negative lap on the exhaust-side of the same port; how far must the slide travel from the point where expansion commences, on the down-stroke, before the port will open to the exhaust?

Ans. When the slide has travelled downwards through $3\frac{1}{2}$ inches, the exhaust-passage will be $\frac{1}{4}$ inch open; consequently, when it has gone through $3\frac{1}{4}$ inches the exhaustion will commence.

88. A slide has $2\frac{1}{2}$ inches lap on the steam-side, and $\frac{1}{4}$ inch lap on the exhaust-side; how far must the slide be moved from the commencement of expansive working till the steam escapes? *Ans.* $2\frac{3}{4}$ inches.

89. The lap on the steam-side of a slide at the upper part is $2\frac{3}{4}$ inches, and the lead $\frac{1}{8}$ inch; how far is the slide from its mean position when the piston is about to commence its downward motion? *Ans.* $2\frac{7}{8}$ inches.

90. The length of an eccentric lever is 13 inches, and the travel of the slide 10 inches; what must be the length of the eccentric lever, that the travel of the slide may be 12 inches?

Let a=length of valve-lifter,

b=throw of eccentric.

Then, by similar triangles, $\frac{10}{a}=\frac{b}{13}$, or $ab=130$.

Again, if x be the length of the eccentric lever when the travel of the slide is 12 inches,

$$\frac{12}{a}=\frac{b}{x} \text{ or } ab=12x.$$

Hence $12x=130$

$$\text{or } x=\frac{130}{12}=10\frac{5}{6} \text{ inches.}$$

91. The length of an eccentric lever is 10 inches, and the

travel of the slide 8 inches. If the lever be shortened an inch, what will be the travel of the slide? *Ans.* 8·88 inches.

92. The travel of a slide is to be increased from 13 to 15 inches; what alteration must be made in the eccentric lever, whose original length is 12 inches?

Ans. It must be shortened $1\frac{5}{7}$ inches.

93. The pressure of steam in a cylinder before expansion is 23 lbs., and the required pressure at the end of the stroke is 12 lbs.; what portion of the stroke must be performed before expansion commences in a cylinder whose length is 5 feet?

Let x = the portion required.

Then, since the pressure of steam varies inversely as the space it occupies,

$$x : 5 :: 12 : 23.$$

$$\text{and } x = \frac{5 \times 12}{23} = \frac{60}{23} = 2 \text{ feet } 7 \cdot 3 \text{ inches.} \quad \textit{Ans.}$$

94. If the pressure of steam in a cylinder whose stroke is 3 feet 7 inches be 60 lbs., and the pressure at the termination of the stroke be 24 lbs.; at what point of the stroke does the expansion commence?

Ans. At 1 foot 5·2 inches from the commencement.

95. The initial pressure of steam, in a cylinder whose stroke is 4 feet 6 inches, is 30 lbs., and expansion commences when 3 feet 2 inches have been performed; find the pressure at the end of the stroke. *Ans.* $21\frac{1}{3}$ lbs.

96. The initial pressure of steam in a cylinder is 58 lbs.: if expansion commence when two-fifths of the stroke has been performed, find the pressure at the termination. *Ans.* $23\frac{1}{3}$ lbs.

97. The initial pressure of steam in a cylinder is 34 lbs., and the final pressure is 20 lbs.; the length of stroke is 3 feet 8 inches; at what point does the expansion commence?

Ans. At 2 feet 1·88 inches.

98. The terminal pressure in a steam-cylinder is required to be 3 lbs above the atmosphere, and expansion begins at 1 foot

from the commencement of the stroke, the whole stroke being 2 feet 9 inches; find the initial pressure. *Ans.* 49½ lbs.

99. If a steam-boiler be loaded to 10 lbs. per square inch, and the engine have 6 feet stroke; find what the pressure will be at the end of the stroke, the steam being cut off after the piston has traversed one foot; find also the *mean* effective pressure.

Ans. Terminal pressure, 4·16 lbs.

Mean pressure, 10·21 lbs. approximately.

100. The length of stroke of a steam-engine is 5 feet 6 inches, and the boiler-pressure 12 lbs. above the atmosphere; the steam is cut off after the piston has traversed 2 feet; find the pressure of the steam in the cylinder when it opens to the exhaust, which takes place 2 inches before the end of the stroke. *Ans.* 10⅛ lbs.

101. The initial pressure in a steam-cylinder is 45 lbs., the length of stroke is 10 feet 9 inches, and the steam is cut off at 3 feet 6 inches; find the terminal pressure.

Ans. 14·8 lbs. nearly.

102. The upper side of an equilibrium-valve is 9 inches in diameter, and the lower side 8 inches; find the power necessary to lift it when the pressure of the steam is 12 lbs. above that of the atmosphere, if the space between the upper and lower valves be a vacuum.

Area of upper side $= \cdot 7854 \times 81 = 63 \cdot 6174$ square inches.
Area of lower side $= \cdot 7854 \times 64 = 50 \cdot 2656$ square inches.
Excess of upper over lower $= 13 \cdot 3518$ square inches,
and pressure on each square inch $= 12 + 15 = 27$ lbs.
$\therefore$ requisite force $= 13 \cdot 3518 \times 27$
$= 360 \cdot 49$ lbs.

103. The upper side of an equilibrium-valve is 10 inches in diameter, and the lower one is 9½ inches; what force must be exerted to open it when the steam has a pressure of 20 lbs. above the atmosphere? *Ans.* 268·3 lbs.

104. The upper side of an equilibrium-valve is 11 inches in

diameter, and the lower side $10\frac{1}{2}$ inches; find what power will be required to lift it if the steam-gauge stands at 15 lbs., and the atmosphere be acting between the two valves. *Ans.* 126 lbs.

NOTE. In the above example, the pressure, 15 lbs., must be used, and not 30 lbs., as would have been the case if there had been a vacuum.

105. A gridiron-valve has 3 orifices, each of which is 2 feet 11 inches by $2\frac{1}{2}$ inches; find the amount of opening, if fully open. *Ans.* 262·5 square inches.

106. The breadth of a steam-port is 3 feet 7 inches, and the maximum opening for steam $3\frac{1}{4}$ inches; find the amount of opening to give the same aperture when a gridiron-valve be used, if the breadth of each aperture be 2 feet 7 inches, and the number of apertures 3. *Ans.* $1\frac{1}{2}$ inches.

107. The diameter of the cylindrical cup which holds the mercury of the condenser-gauge is $1\frac{1}{2}$ inches, and that of the glass tube is $\frac{5}{10}$th inch; when the mercury stands at 26 inches by the fixed scale, find the correct height (not taking into account the space occupied by the iron tube within the glass tube).

Since the mercury standing in the tube has come from the cup, the level in the latter must have sunk accordingly; and the amount of this depression must be added to the indicated column.

Let $x =$ the depression in the cup corresponding to the rise of 26 inches of the tube;

Then $x\,(\cdot7854\times1\cdot5^2-\cdot7854\times\cdot3^2)=26\times\cdot7854\times\cdot3^2$;

or, $x\,(1\cdot5^2-\cdot3^2)=26\times\cdot3^2$

$x\,(2\cdot25-\cdot09)=26\times\cdot09$

$2\cdot16x=26\times\cdot09$

$$x=\frac{26\times\cdot09}{2\cdot16}=1\cdot08 \text{ inches.}$$

Hence, the true height $=26+1\cdot08=27\cdot08$ inches.

108. The diameter of the cup containing the mercury of a condenser-gauge is 2 inches, and that of the glass tube is ·3 inches; what is the true height of the mercury when it stands at 27·5 inches by the fixed scale? *Ans.* 28·13 inches.

109. From the same data as in the previous question, what will be the height of the mercury, according to the scale, if the true height be 27 inches?

If x be the fall of mercury in cup, the mercury has risen in the tube $27-x$ inches;

whence, proceeding as before, $x=\cdot 607$ inches;

and the height by the scale is $27-x=26\cdot 4$ inches.

110. The diameter of the cup containing the mercury of a condenser-gauge is $2\frac{1}{2}$ inches, and that of the glass tube is 4 inches; the tube is inverted over an iron tube (passing through the cup, and communicating with the condenser), whose diameter is $\cdot 2$ inches; if the mercury stand at 28 inches by the fixed scale, what is the true height?

The effective area of the tube is $\cdot 7854\times\cdot 4^2-\cdot 7854\times\cdot 2^2$; and if this be used, the process is the same as in the former cases. *Ans.* $28\cdot 55$ inches.

111. The area of a piston is $5944\cdot 67$ square inches; find the diameter of the air-pump, which is half that of the cylinder; find also, the capacity of the pump, supposing it to be similar to the cylinder.

Since circles are to each other as the squares of their diameters, the area of the air-pump bucket is $\frac{1}{4}$th that of the piston.

Hence its area $=\frac{5944\cdot 67}{4}=1486\cdot 1675$ square inches,

and the diameter $=\sqrt{\frac{1486\cdot 1675}{\cdot 7854}}$

$=\sqrt{1879\cdot 51}$

$=43\cdot 3$ inches;

and the content is $\frac{1}{8}$th that of the cylinder.

112. If the area of a steam-piston be $881\cdot 41$ square inches, and the diameters of the steam-piston and of the air-pump be as $1:\cdot 6$, find the diameter of the latter. *Ans.* $20\cdot 1$ inches.

113. Engines of 1000 collective horse-power are to be put into a steam-ship, and the number of cylinders is to be 4; find

the diameter of each steam-piston, allowing 21 square inches of surface for each horse-power. *Ans.* 81·76 inches.

114. Allowing the same amount of surface per horse-power, find the power of a pair of engines, the diameter of the cylinder being 51½ inches. *Ans.* 198·4 horse-power.

115. Find the space for steam both above and below the piston of a cylinder: diameter of cylinder, 74 inches; height of do., 8 feet 10 inches; mean thickness of piston, 9 inches; clearance, ½ inch at each end; diameter of piston-rod 9 inches.

(1) For space below the piston:

$$\text{Area of piston} = \cdot 7854 \times 74^2$$
$$= 4300 \cdot 85 \text{ square inches;}$$

and height of cylinder for steam below the piston

$$= 106 - 9\tfrac{1}{2} \text{ inches} = 96\tfrac{1}{2} \text{ inches;}$$

$\therefore$ space for steam below piston

$$= 415{,}025 \text{ cubic inches,}$$
$$= 240 \text{ cubic feet.}$$

(2) For space above piston, deduct from the foregoing the room occupied by piston-rod, viz. $\cdot 7854 \times 9^2 \times 96\tfrac{1}{2}$,

$$= 6139 \text{ cubic inches,}$$
$$= 3 \cdot 5 \text{ cubic feet;}$$

hence space for steam above piston $= 240 - 3 \cdot 5 = 236 \cdot 5$ cubic feet.

116. The lever of the overflow-valve of a feed-valve box is 9 inches long, and the valve-spindle is 4 inches from the fulcrum; the weight at the end of the lever is 12 lbs., and diameter of valve 2 inches; find the pressure of water when the valve lifts.

Since by the property of the lever, the pressure exerted is inversely as the distance from the fulcrum, the effect produced by the weight on the valve is $\frac{9}{4} \times 12$ lbs. $= 27$ lbs., which is distributed over a valve 2 inches in diameter.

$$\text{Now, area of valve} = \cdot 7854 \times 4$$
$$= 3 \cdot 1416 \text{ square inches;}$$

$$\therefore \text{ pressure per inch} = \frac{27}{3 \cdot 1416} = 8 \cdot 6 \text{ lbs. nearly.}$$

117. The lever of the overflow-valve of a feed-valve box is

12 inches long, and the valve-spindle is 4 inches from the fulcrum, the weight at the end of the lever being 10 lbs., and diameter of the valve 2 inches; find the weight on each square inch.

Ans. 9·5 lbs.

118. The lever of the overflow-valve of a feed-valve box is 7 inches long, and the valve-spindle is 3 inches from the fulcrum, the weight at the end of the lever being 14 lbs., and the diameter of the valve $2\frac{1}{4}$ inches; find the weight on each square inch.

Ans. 8·23 lbs.

119. The overflow-valve of a feed-valve box is $2\frac{1}{2}$ inches in diameter, and it is to be loaded to 12 lbs. per square inch by means of a weight acting at the end of a lever; the lever being 10 inches long, and the spindle of the valve $3\frac{1}{2}$ inches from the fulcrum; find the weight.

Area of valve $= \cdot 7854 \times 2 \cdot 5^2$

$= 4 \cdot 9$ square inches.

Required pressure on do. $= 4 \cdot 9 \times 12 = 58 \cdot 8$ lbs.

Let w = weight on lever.

Then $w \times 10 = 58 \cdot 8 \times 3 \cdot 5$

$= 205 \cdot 8$

$w = 20 \cdot 6$ lbs. *Ans.*

120. The overflow-valve of a feed-valve box is 3 inches in diameter, and it is to be loaded to 15 lbs. per square inch by means of a lever, whose length is 14 inches, and the distance from the spindle to the fulcrum is $4\frac{1}{2}$ inches; what weight must be attached to the end of the lever? *Ans.* 33·83 lbs.

121. The overflow-valve of a feed-valve box is $2\frac{3}{4}$ inches in diameter, and it is loaded to 14 lbs. per square inch by means of a lever 10 inches long and a weight of 30 lbs. attached to the end of the lever; find the distance of the spindle from the fulcrum. *Ans.* 3·6 inches.

122. The overflow-valve of a feed-pump is 4 inches in diameter, the length of lever is 16 inches, and the valve 4 inches from the fulcrum; what weight must be attached to the end of the lever to balance the pressure of steam in the boiler when

working at 11 lbs.? would you make the actual weight more or less than this? *Ans.* 34·5 lbs.

123. The waste water-pipes of the engines of H.M.S. *Sidon* are 16 feet above the bottom of the hot-well, the condenser-gauge stands at 26 inches, and the weather-barometer at 30 inches; find the pressure on 10 square feet of the bottom of the hot-well. *Ans.* 12·8 tons nearly.

124. Find the friction-surface of the *Terrible's* four cylinders, —stroke 8 feet, diameter 72 inches,—and compare it with what it would have been if the same power had been developed from two cylinders of the same stroke.

$$\text{Surface of each cylinder} = 3\cdot1416\times6\times8$$
$$= 150\cdot7968 \text{ square feet.}$$
$$\therefore \text{ total surface} = 603\cdot1872 \text{ square feet.}$$

Again, if x be the diameter of each cylinder, when single-cylinder engines are used, since the total area of piston must be the same, we must have

$$2\times\cdot7854\times x^2 = 4\times\cdot7854\times6^2$$
$$\text{or } x^2 = 2\times6^2$$
$$= 72 \text{ square feet.}$$
$$\therefore x = \sqrt{72} = 8\cdot48 \text{ feet.}$$

$\therefore$ surface of each cylinder would be

$$3\cdot1416\times8\cdot48\times8$$
$$= 213\cdot126 \text{ square feet;}$$
$$\text{and total surface} = 426\cdot252 \text{ square feet.}$$

$\therefore$ friction-surface of single cylinders : do. do. double cylinders

$$:: 426 : 603$$
$$:: 142 : 201$$
$$:: 7 : 10 \text{ nearly.}$$

125. The cylinder of an engine having become full of sea-water from priming, what weight will the piston have to raise in getting rid of it? Diameter of cylinder 90 inches, and length of stroke 7 feet (neglecting the space occupied by the piston-rod). *Ans.* 8·83 tons.

126. The stroke of an engine is 7 feet 6 inches, and the diameter of the paddle-wheel is usually about eight times the length of the crank; find the diameter of the paddle-wheel.

(1) $\frac{7\text{ft. }6\text{in.}}{2}=3$ feet 9 inches, the length of crank.

(2) 3 ft. 9 in. $\times 8=30$ feet, the diameter of paddle-wheel.

127. Find the diameter of a paddle-wheel for an engine whose stroke is 8 feet. *Ans.* 32 feet.

128. Find the diameter of a paddle-wheel for an engine whose stroke is 6 feet 4 inches. *Ans.* 25 feet 4 inches.

129. The diameter of a paddle-wheel is 30 feet, and the width of the paddle-boards 2 feet 6 inches; find the rate in knots per hour of the outer and inner edge of the paddle-boards, and of the centre of pressure,* the number of revolutions being 15 per minute. *Ans.* Rate of outer edge 13·95 knots.
inner edge 11·62
centre of pressure 13·17

130. The diameter of a paddle-wheel is 26 feet, and the number of revolutions per minute 16; find the rate in knots per hour of the inner and outer edge of the paddle-boards, whose width is 2 feet 4½ inches; find also the rate of the centre of pressure. *Ans.* 12·9, 10·54, and 12·13 knots.

131. A paddle-wheel is 30 feet in diameter, and the number of boards is the same as the number of feet in the diameter; the boards are 2 feet 8 inches in width; find their distance apart at the inner and outer edges.

Since the outer circumference $=3\cdot1416\times30$ feet
and the number of boards is 30
$\therefore$ their distance apart at the outer edge is 3·1416 feet.
Also, since the inner diameter $=30$ feet -5 feet 4 inches
$=24$ feet 8 inches $=296$ inches,
$\therefore$ the inner circumference $=3\cdot1416\times\frac{296}{12}=77\cdot49$ feet;
and $\frac{77\cdot49}{30}=2\cdot583$ feet.

* The centre of pressure of the board is assumed to be at two-thirds the depth of the board below the upper edge.

132. A paddle-wheel is fitted with 20 boards; if its diameter be 9 feet, what is the space between them at the inner and outer edges, their width being 1 foot 1½ inch?

Ans. 1·415 feet and 1·06 feet.

133. If a paddle-wheel be fitted with 20 boards, and its diameter be 12 feet; find the space between the boards at the outer edge. *Ans.* 1·88 feet.

134. The extreme diameter of a paddle-wheel is 28 feet, and the breadth of the boards 2 feet 3 inches, the number of revolutions being 16; and it is found that the speed of the ship is the same as that of the inner edge of the boards, while the rate of the wheel is estimated in the usual manner, viz. the same as that of a point of the board at one-third the breadth from the outer edge; find the slip of the paddle per cent.

Ans. 11·3 per cent nearly.

135. A C B is a beam, whose middle point C is connected with a radius-bar C D; D is a fixed point round which C D works, and B moves in the straight line B D; if A C = C B = C D, prove that the point A will accurately describe a straight line.

136. What power, acting at right angles to a crank through a whole revolution, will produce the same mean effect as the force of 10 tons acting on the piston throughout the up and down strokes?

Let l = length of stroke,

c = radius of crank.

Then, since press. on piston × the whole stroke

= force on crank × the whole revolution;

$$\therefore \text{force on crank} = \frac{10 \times 2l}{2\pi c}$$

But $l = 2c$.

$$\therefore \text{force on crank} = \frac{20}{3 \cdot 1416}$$

= 6 tons 7·3 cwt.

137. If the mean pressure requisite to turn a crank be 5 tons, what must be the mean pressure on the piston?

Ans. 7 tons 17·14 cwt.

138. If the pressure of the water on the paddles of a steamer be 4 tons, what force on the pistons will be necessary to drive them: the stroke of the engine being 8 feet, and the diameter of the wheels 34 feet? *Ans.* 13·35 tons on each piston.

139. A circular tube is replaced by 4 circular tubes of the same total volume; show that the heating-surface is thereby doubled.

140. Compare the heating-surface afforded by two sets of tubes, the first set consisting of 800 3-inch tubes, and the second of 1000 $2\frac{1}{2}$-inch tubes. *Ans.* 24 : 25.

141. If the tubes of a set of boilers (3500, $2\frac{3}{4}$-inch tubes) be replaced by the same number of 3-inch tubes, in what proportion will the heating surface be increased?

Ans. The amount will be $\frac{1}{11}$th more.

142. There are 3000 tubes in a set of marine boilers, their *external* diameter being 3 inches, thickness of metal $\frac{1}{4}$ inch, and length 6 feet; find the amount of power developed,—16 square feet of surface being equivalent to one horse-power.

Ans. 736·2 horse-power.

143. The dimensions of a boiler are 20 feet by 14, and the height of the water in it 11 feet; it contains 200 tubes of 3 inches *external* diameter and 6 feet long, and 3 fire-places, each being 6 feet by 2 feet 6 inches, and 4 feet high; what is the quantity of water in the boiler (the fire-box, &c., not being taken into account)? *Ans.* 2841 cubic feet.

144. The shell of a cylindrical boiler is 5 feet 6 inches in diameter, and 10 feet long; a cylindrical flue runs through it, from end to end, of 20 inches in diameter; find the space remaining for water and steam. *Ans.* 215·75 cubic feet.

145. The shell of a cylindrical boiler is 5 feet 3 inches in diameter, and $9\frac{1}{2}$ feet long; it has a cylindrical flue running through it of 1 foot 7 inches diameter; find the cubic contents of the boiler. *Ans.* 186·94 cubic feet.

146. If the flues mentioned in the last two questions be in the lower half of the boiler, find the space for steam and water respectively when filled with water to the centre of the shell.

Ans. For steam, 118·75 and 102·82 cubic feet respectively; and for water, 97 and 84·12 cubic feet respectively.

147. The diameters of an oval steam-dome, with a flat top, are 3 feet 3 inches and 2 feet 6 inches, and its height is 3 feet 9 inches; find the quantity of steam it will contain, and the quantity of water from which the steam was formed, the valve being loaded to 45 lbs.

The greater diameter $=39$ inches.

The lesser diameter $=30$ inches.

Hence the area of the end $= \cdot 7854 \times 39 \times 30$

$=918 \cdot 918$ square inches

$=6 \cdot 381$ square feet;

also, $6 \cdot 381 \times 3 \cdot 75 = 23 \cdot 929$ cubic feet for steam.

Again, since the pressure of steam $= 45+15=60$ lbs.

and the relative volume of do. $=468$,*

$\therefore$ volume of water forming the steam $= \frac{23 \cdot 929}{468}$ cubic feet

$= \frac{23 \cdot 929}{468} \times 1728$ cubic in.

$=88\frac{1}{3}$ cubic inches nearly.

148. Find the surface of the dome specified in the previous question. *Ans.* 33·87 square feet.

149. Find the content of a dome, whose form is a cylinder with a hemispherical top, the diameter being 2 feet 3 inches, and height of the cylindrical portion 2 feet 9 inches.

Area of base of cylinder $= 27^2 \times \cdot 7854$

$=572 \cdot 5566$ square inches;

$\therefore$ content of cylinder $= 572 \cdot 5566 \times 33$

$=18894 \cdot 3578$ cubic inches.

* See Marine Engine, Table A.

Again, if content of sphere (diameter 27 inches)
$= 10306 \cdot 0188$ cubic inches;
$\therefore$ content of hemispherical portion
$= 5153 \cdot 0094$ cubic inches,
$= 13 \cdot 9163$ cubic feet nearly.

150. Find the surface of the dome specified in the last question.

Surface of cylindrical portion
$= 3 \cdot 1416 \times 27 \times 33 = 2799 \cdot 1656$ square inches.
Again, surface of a sphere
$=$ 4 times area of circle of the same diameter
$= 4 \times \cdot 7854 \times$ diameter;
$\therefore$ surface of hemispherical portion
$= 2 \times \cdot 7854 \times 27^2$
$= 1145 \cdot 1132$ square inches;
and the whole surface of the dome
$= 2799 \cdot 1656 + 1145 \cdot 1132$
$= 3944 \cdot 2788$ square inches
$= 27 \cdot 39$ square feet.

151. Find the content of a steam-dome, having a hemispherical top, the diameter of the cylindrical portion being 3 feet 7 inches, and height 5 feet 3 inches. *Ans.* $64 \cdot 93$ cubic feet.

152. Find the surface of the dome specified in the previous question. *Ans.* $79 \cdot 27$ square feet.

153. Find the content of a steam-dome, which has a hemispherical top, the diameter of the cylindrical portion being 3 feet 2 inches, and height 4 feet 5 inches. *Ans.* $43 \cdot 08$ cubic feet.

154. Find the weight of a set of fire-bars for 16 fire-places, 30 in each fire-place, the bars being 3 feet long and $1\frac{1}{2}$ inch thick on the top, tapering away to $\frac{1}{2}$ an inch at the lower side, their depth being 4 inches, and the weight of a cubic foot of iron 475 lbs.

$1\frac{1}{2} + \frac{1}{2} = 2$, the half of which is the mean thickness of the bars.

$$4 \times 36 = 144 \text{ cubic inches}$$
$$= \tfrac{1}{12} \text{ cubic feet.}$$
$$\text{Number of bars} = 30 \times 16 = 480,$$
$$\text{cubic feet in 480 bars} = \frac{480}{12} = 40.$$
$$\text{Hence weight in lbs.} = 475 \times 40 = 19{,}000 \text{ lbs.}$$

155. Find the space occupied in a boiler by 200 tubes, each 6 feet long and 3 inches external diameter.

Ans. 58·9 cubic feet.

156. The diameter of a safety-valve is 8 inches, and that of the lead cylindrical weight with which it is loaded is $9\frac{3}{4}$ inches, and the cylinder is 16 inches in depth; find the pressure of steam when the valve lifts, the weight of a cubic foot of lead being 717 lbs.

(1) To find the weight of the lead:

$$\text{Volume of the cylinder} = \cdot 7854 \times 9 \cdot 75^2 \times 16$$
$$= \cdot 7854 \times 1521.$$
$$\text{Weight of cylinder} = \frac{\cdot 7854 \times 1521 \times 717}{1728}$$
$$= \cdot 7854 \times 631 \cdot 11.$$

(2) Area of valve $= \cdot 7854 \times 64$;

$$\therefore \text{ pressure per square inch} = \frac{631 \cdot 11}{64}$$
$$= 9 \cdot 86 \text{ lbs.}$$

157. The diameter of a safety-valve is $6\frac{1}{2}$ inches; it is loaded with an iron weight of 9 inches diameter, and 18 inches depth; find the pressure of the steam when the valve lifts, the weight of a cubic foot of iron being 440 lbs. *Ans.* 8·78 lbs.

158. The diameter of a safety-valve is 10 inches, which is loaded with a lead cylindrical weight of 12 inches diameter, and 22 inches depth; what is the pressure of steam when the valve lifts? *Ans.* 13·145 lbs.

159. If a square inch be allowed as the area of a safety-valve for every 15 square feet of heating surface, what must be the diameter of a valve for a boiler whose heating surface is 1000 square feet? *Ans.* 9·2 inches.

160. A leaden cylinder is 9 inches in depth; find its diameter, that when attached to an annular-valve, whose diameters are 7 and 3 inches respectively, the valve may not lift till the pressure of steam is 21 lbs. *Ans.* 14·98 inches.

161. An iron cylinder is 9 inches in depth, and the weight of a cubic foot of the iron is 434 lbs.; find its diameter, that when attached to a safety-valve of 9 inches diameter, it may allow steam of 7 lbs. pressure to escape.

Ans. 15·84 inches.

162. A leaden cylinder of 9 inches diameter and 15 inches depth is attached to the safety-valve of a boiler; required its diameter that it may lift when the pressure of steam is 10 lbs.

Let x=diameter of the valve.

Then pressure on valve$=\cdot 7854\times x^2\times 10$.

But weight of cylinder$=\frac{\cdot 7854\times 9^2\times 15\times 717}{1728}$

$\therefore\ \cdot 7854\times x^2\times 10=\frac{\cdot 7854\times 9^2\times 15\times 717}{1728}$

and $x^2=\frac{81\times 15\times 717}{17280}$

$=50\cdot 42$.

$x=7\cdot 1$ inches. *Ans.*

163. A leaden cylinder of 10 inches diameter and 16 inches depth is attached to an annular-valve whose outer diameter is 9 inches; find the inner diameter, that the valve may lift when the pressure of steam is 15 lbs. *Ans.* 6·06 inches.

164. A leaden cylinder of 12 inches diameter and 20 inches depth is attached to a valve, whose diameter is required, that it may lift when the pressure of steam is 8 lbs.

Ans. 12·22 inches.

165. The diameter of the leaden weight with which a valve is loaded is 12 inches, and the diameter of the valve is $9\frac{1}{2}$ inches; find the depth of the cylinder, that the steam may escape when the pressure is 14 lbs.

Area of valve is $\cdot 7854 \times 9 \cdot 5 = \cdot 7854 \times \frac{361}{4}$

pressure on do. $= \cdot 7854 \times \frac{361}{4} \times 14$

$= \cdot 7854 \times 1263 \cdot 5.$

Area of base of cylindrical weight

$= \cdot 7854 \times 12^2 = \cdot 7854 \times 144.$

Let now x = depth of cylinder.

Then volume of cylinder $= \cdot 7854 \times 144 \times x,$

and weight of do. $= \frac{\cdot 7854 \times 144 \times x \times 717}{1728}$

$= \frac{\cdot 7854 \times x \times 717}{12}$

Hence, since the weight = pressure to lift the valve,

$$\frac{\cdot 7854 \times x \times 717}{12} = \cdot 7854 \times 1263 \cdot 5,$$

and $x = \frac{12 \times 1263 \cdot 5}{717}$

$= 21 \cdot 14$ inches. *Ans.*

166. The diameter of a leaden weight, with which a safety-valve is loaded, is $10\frac{1}{4}$ inches, and the diameter of the valve is $8\frac{1}{4}$ inches; find the depth of the cylinder, that the steam may escape at 11 lbs. pressure. *Ans.* 17·17 inches.

167. The diameter of a leaden cylindrical weight is $13\frac{3}{4}$ inches; find the depth of the cylinder, that when attached to a safety-valve of $10\frac{1}{2}$ inches diameter, the steam may escape when it attains 12 lbs. pressure. *Ans.* 16·86 inches.

168. A leaden cylinder is 14 inches in depth; find its diameter, that when attached to a safety-valve of 9 inches diameter, the valve may not lift till the pressure of steam is 15 lbs.

Let x = the diameter of the cylinder,

$\therefore \cdot 7854 \times x^2$ = the area of do.

and volume of cylinder $= \cdot 7854 \times x^2 \times 14$

and weight of ditto $= \frac{\cdot 7854 \times x^2 \times 14 \times 717}{1728}$

$= \frac{\cdot 7854 \times x^2 \times 10038}{1728}$

Again, area of safety-valve $= \cdot 7854 \times 9^2$,

and pressure on ditto $= \cdot 7854 \times 81 \times 15$;

hence $\cdot 7854\ x^2 = \frac{\cdot 7854 \times 81 \times 15 \times 1728}{10038}$

$$\therefore\ x^2 = \frac{81 \times 15 \times 1728}{10038}$$

$$= 209 \cdot 1571.$$

$$x = 14 \cdot 46 \text{ inches.}$$

169. The safety-valve of a boiler is 8 inches in diameter; but not being large enough, a second one was added; what should be its diameter, that both together may have the same area as a valve of 10 inches diameter? *Ans.* 6 inches.

170. A safety-valve of 9 inches diameter is raised an inch; compare the aperture for the escape of steam with what it would be if the valve were entirely removed. *Ans.* As 4 : 9.

171. Find the least height to which a valve of 9 inches diameter must be raised to allow a free egress for steam.

Ans. $2\frac{1}{4}$ inches.

172. To what height must an annular-valve of 9 inches and 6 inches diameters respectively be raised, that the opening for the egress of steam may be the same as it would be if the valve were entirely removed? *Ans.* $\frac{3}{4}$ inch.

173. A safety-valve of 9 inches diameter is replaced by an annular-valve of 6 inches (outer diameter); what must be its inner diameter that it may allow the same total opening for steam? *Ans.* 3 inches.

174. A safety-valve of 12 inches external diameter is replaced by an equally efficient annular-valve, whose outer diameter is 10 inches; what is its inner diameter? *Ans.* 2 inches.

175. The safety-valve of a boiler is $9\frac{1}{2}$ inches in diameter, and the iron weight connected with it is a cylinder, whose diameter is 12 inches, and depth 20 inches; required the pressure to

which the valve is loaded: 1. per square inch; 2. per circular inch, the weight of a cubic foot of iron being 441 lbs.

Ans. 8 and 6·36 lbs.

176. The legs of a steam-gauge are of unequal bore, so that when the mercury rises 12 inches in the one, it sinks 8 inches in the other; compare their diameters.

Let d_1 and d_2 be the diameters.

Then, since the quantity of mercury which rises in the one leg is equal to that which has gone from the other,

$$\cdot 7854 \times d_1^2 \times 12 = \cdot 7854 \times d_2^2 \times 8;$$

$$\therefore 12 d_1^2 = 8 d_2^2,$$

$$\text{and } \frac{d_1^2}{d_2^2} = \frac{8}{12} = \frac{2}{3}$$

$$\text{or } d_1 : d_2 :: \sqrt{2} : \sqrt{3}.$$

177. If the mercury rise 7 inches in one of the legs of a steam-gauge, when it sinks 10 inches in the other, compare the diameters of the bores. *Ans.* $\sqrt{10} : \sqrt{7}$.

178. If the mercury rise 10 inches in one of the legs of a steam-gauge, when it sinks 15 inches in the other, compare their areas. *Ans.* As 3 : 2.

179. The true height of the mercury in a correct gauge is 13 inches, but in a gauge whose legs are of unequal bore the apparent height was 10 inches; compare the diameters of the bores.

Let x be the depression in the one leg,

and d_1 its diameter,

d_2 the diameter of the other leg.

Then $\cdot 7854 \times d_1^2 \times x = \cdot 7854 \times d_2^2 \times 10$,

$$\text{or } d_1^2 x = d_2^2 \times 10.$$

Again, since the correct height is 13,

$$x + 10 = 26,$$

$$\text{or } x = 26 - 10 = 16;$$

$$\therefore d_1^2 \times 16 = d_2^2 \times 10,$$

$$\text{or } \frac{d_1^2}{d_2^2} = \frac{5}{8}$$

$$\therefore \frac{d_1}{d_2} = \frac{\sqrt{5}}{\sqrt{8}}.$$

180. The pressure of steam in a boiler is 14 lbs., but the steam-gauge (the legs of which are unequal in diameter) indicated 16; compare the diameters. *Ans.* $\sqrt{3} : \sqrt{4}$.

181. The true pressure of steam in a boiler was 11 lbs., and the steam-gauge, from inequality in the size of the legs, indicated 10 lbs.; compare their diameters. *Ans.* $\sqrt{5} : \sqrt{6}$.

182. Find the ratio of the diameters of the legs of a steam-gauge, that every pound pressure in the boiler may correspond to $1\frac{1}{4}$ inches on the scale.

Since every 2 inches correspond to one pound pressure, the elevation in the one leg and the depression in the other are equal to 2 inches.

Hence the depression $= \frac{3}{4}$ inch.

Let d_1 d_2 be the diameters.

Then $\cdot 7854\ d_1^2 \times 1\frac{1}{4} = \cdot 7854 \times d_2^2 \times \frac{3}{4}$;

or $5d_1^2 = 3d_2^2$.

$$\therefore \frac{d_1}{d_2} = \frac{\sqrt{3}}{\sqrt{5}}.$$

183. Find the ratio of the diameters of the legs of a steam-gauge, that half-an-inch on the scale may indicate a pound pressure of the steam. *Ans.* $\sqrt{3} : 1$.

184. Find the ratio of the diameters of the legs of a steam-gauge, that $1\frac{1}{2}$ inches on the scale may indicate a pound pressure of the steam. *Ans.* $1 : \sqrt{3}$.

185. If the outer leg of the steam-gauge were to communicate with some vessel from which the air had been exhausted, to what height would the mercury rise if the boiler were working at 12 lbs. pressure?

Since $12 + 15 = 27$ lbs.

and a pressure of 15 lbs. corresponds to 30 inches of mercury,

$\therefore$ 15 : 30 : : 27 : $27 \times 2 = 54$ inches.

Hence $\frac{54}{2} = 27$ inches, the height required.

186. If the outer leg of a steam-gauge were connected with

the condenser, to what height would the mercury rise when the pressure of the steam in the boiler is 14 lbs., and the condenser-gauge stands at 27 inches? *Ans.* 27·5 inches.

187. If the legs of a steam-gauge be of unequal bore, and A and B be the areas of their sections (of which B is the area of that in connection with the boiler); then if p be the pressure per square inch to which the valve is loaded, s the weight of a cubic inch of mercury, h the height of the index of the gauge when the steam is blowing off,

$$\frac{A}{B}=\frac{sh}{p}-1.$$

188. Find the weight of a funnel of the following dimensions: length 40 feet; diameter 8 feet; the plates are 6 feet long, and the thickness of the iron is $\frac{1}{8}$ inch, except the two lower lengths, which are $\frac{1}{4}$ inch.

$$3\cdot1416\times8=25\cdot1328 \text{ (the circumference)},$$
$$25\cdot1328\ (40+12)\times\tfrac{1}{8}\times\tfrac{1}{12}=13\cdot6 \text{ cubic feet.}$$
$$\therefore \text{ weight in lbs.}=6004, \text{ or 2 tons 13 cwt.}$$

189. Find the quantity of air circulating round a funnel, whose diameter is 6 feet, and the diameter of the air-casing 6 feet 8 inches; the length of the casing being 10 feet.

Ans. 66·32 cubic feet.

190. Find the number of square feet of iron in the funnel of H.M.S. *Wellington's* boilers; diameter 8 feet 6 inches, and height 40 feet. *Ans.* 1068 feet.

191. Find the number of square feet in the funnel of H.M.S. *Gladiator's* boilers; diameter 7 feet 6 inches, and height above the boilers 40 feet; find also what space the air-casing occupies on the deck, allowing 4 inches between it and the funnel.

Ans. 942·48 square feet, and 52·38 square feet respectively.

192. The diameter of a brass reverse-valve is the same as that of the aperture into which it is fitted, and its thickness is 3 inches; find the pressure of the steam when the valve begins to lift, and the force tending to collapse aside of the boiler, whose

dimensions are 13 feet by 12: the weight of a cubic foot of brass being 525 lbs.

Let A = the area of the base of the valve,

p = pressure of steam below the atmosphere.

Now 3 A = cubic inches in the valve,

$\frac{3 A \times 525}{1728}$ = weight of valve in pounds,

and p A = pressure to lift the valve.

$$\therefore p A = \frac{3 \times A \times 525}{1728}$$

$$\text{or } p = \frac{1575}{1728} = \cdot 91 \text{ lbs.}$$

And force tending to collapse the boiler

$$= \frac{1575}{1728} \times 13 \times 12 \times 144 \text{ lbs.}$$

$$= 1575 \times 13 \text{ lbs.} = 20475 \text{ lbs.}$$

$$= 9 \text{ tons } 2 \text{ cwt. } 3 \text{ qrs. } 7 \text{ lbs.}$$

193. If a reverse-valve be kept in its place by its weight, and the material be brass; what must be the thickness that it may open when the pressure of the steam within the boiler is 2 lbs. below that of the atmosphere, the weight of a cubic foot of brass being 525 lbs., and the diameter of the weight the same as that of the valve? *Ans.* 6·3 inches.

194. The diameter of a reverse-valve is 3 inches, and that of the brass weight 4 inches. If the thickness of the weight be 2 inches, find the pressure of the steam in the boiler when the valve begins to lift. *Ans.* 13·98 lbs.

195. If the reverse-valve of a boiler be a solid brass cylinder 4 inches long, what will be the pressure to collapse a boiler when it is on the point of acting, the weight of a cubic foot of brass being 525 lbs.? *Ans.* 1·21 lbs.

196. If the diameter of a reverse-valve be $2\frac{1}{2}$ inches, and that of the brass weight be 3 inches, and its thickness 3 inches; find the pressure of steam in the boiler when the valve begins to lift. *Ans.* 13·68 lbs.

197. A reverse-valve (open to the atmosphere) is 3 inches in diameter, and is kept at rest by its own weight, 10 lbs.; what will be the pressure of steam in the boiler when the valve opens?

Ans. 13·34 lbs.

198. If the water-gauge of a boiler were open at the top to the atmosphere, what must be the length of the tube; the boiler working at 10 lbs. pressure, and a column of water 34 feet high being supposed to be equal in weight to the pressure of the atmosphere (14·75 lbs.)?

lbs. feet. lbs. feet.
As 14·75 : 34 :: 10 : 23·05

Hence height required = 23·05 feet.

199. The bottom of the boilers of H.M.S. *Edinburgh* being 22 feet below the level of the sea, what height of water will remain in the boilers after blowing out as much as possible, if the pressure of steam be 6 lbs.?

lbs. ft. lbs.
As 14·75 : 34 :: 6 : the depth of water-level in boiler below the level of the sea;

Hence depth required $= \frac{6 \times 34}{14 \cdot 75} = \frac{204}{14 \cdot 75} = 14$ feet nearly,

and the water remaining in the boiler = 8 feet.

200. Find how much water may be blown out of the boilers of H.M.S. *Wellington*, the pressure of steam in boiler being 14 lbs., and draught of water of the ship 26 feet.

Ans. All can be blown out.

201. The level of the water in a marine boiler is 6 feet above the level of the sea, and the pressure of the steam 7 lbs.; what is the force per square inch in blowing out? *Ans.* 9·6 lbs.

202. A feed-valve of Seaward's construction is 4 inches in diameter, and the area of the brine-valve is $\frac{1}{4}$th that of the feed; find its diameter. *Ans.* 2 inches.

203. A feed-valve is 5 inches in diameter, and the area of the brine-valve is $\frac{1}{8}$d that of the feed-valve; find its diameter.

Ans. 2·9 inches.

204. If the diameter of a feed-valve be double that of a brine-valve, and the area of the latter be 3 square inches, find the area of the former. *Ans.* 12 square inches.

205. Find how much water will be extracted from a boiler in an hour by a brine-pump making 18 strokes a minute; its diameter being 3 inches, and stroke 10 inches, the pump being $\frac{2}{3}$ds full at each stroke.

Capacity of pump $= \cdot 7854 \times 9 \times 10$

$= 70 \cdot 686$ cubic inches;

$\therefore$ quantity delivered at each stroke

$= \frac{2}{3} \times 70 \cdot 686$

$= 47 \cdot 124$ cubic inches;

and quantity delivered in an hour

$= 18 \times 60 \times 47 \cdot 124$

$= 50893 \cdot 92$ cubic inches.

But a cubic foot of sea-water weighs 64 lbs., $\therefore$ the weight discharged per hour is $1884 \cdot 96$ lbs.

$= \cdot 84$ of a ton.

206. How much sea-water will a brine-pump, $3\frac{1}{4}$ inches in diameter, and 12 inches stroke, extract from a boiler in an hour, when making 15 strokes a minute, the pump being $\frac{2}{3}$ds full at each stroke? *Ans.* $34 \cdot 56$ cubic feet.

207. What weight of water will a brine-pump, $\frac{3}{4}$ths filled at each stroke, deliver in an hour, its dimensions being $3\frac{1}{2}$ inches in diameter, 14 inches stroke, and number of strokes per minute 12?

Ans. $1 \cdot 2$ tons.

208. The diameter of the feed-pipe of an engine is $\frac{1}{6}$th that of the waste-water-pipe, and the area of the latter is 157 square inches; find the diameter of the former.

$\sqrt{\frac{157}{\cdot 7854}} = 14 \cdot 14$ inches, diameter of waste-water-pipe;

and $\frac{14}{6} = 2 \cdot 356$ inches, diameter of feed-pipe.

209. The diameter of a feed-pipe is $3\frac{1}{2}$ inches, and the area of the waste-water-pipe is 26 times that of the feed; find its diameter. *Ans.* 17·84 inches.

210. If the areas of a waste-water-pipe and of a feed-pipe are as 29 to 1, and the diameter of the former be 18 inches, find that of the latter. *Ans.* 3·34 inches.

211. Find the quantity of water discharged in an hour by a bilge-pump whose diameter is 6 inches, and stroke 2 feet 6 inches; the number of strokes being 18 per minute, and the pump $\frac{2}{3}$ds full at each stroke.

$$\cdot 7854 \times 36 = 28 \cdot 27, \text{ area of bucket in square inches;}$$
$$\text{and } 28 \cdot 27 \times 20 = 565 \cdot 4 \text{ cubic inches,}$$
$$\frac{565 \cdot 4 \times 18 \times 60}{1728} = 353 \cdot \dot{4} \text{ cubic feet.}$$

212. How much water will the bilge-pumps of a *pair* of marine engines discharge in an hour if $\frac{2}{3}$ds filled at each stroke, the number of strokes per minute being 14, and the length of stroke and diameter being 2 feet 10 inches and $8\frac{1}{2}$ inches respectively? *Ans.* 1251 cubic feet.

213. What force is required to raise an air-pump bucket 2 feet in diameter, the water-level outside the ship being 20 feet above the bucket, and the condenser-gauge standing at 28 inches?

To find the pressure arising from 20 feet of water:

	feet.	lbs.		feet.	lbs.
As	34	: 14·75	::	20	: 8·7

Hence pressure per square inch of bucket
$$= 8 \cdot 7 + 14 \cdot 75 - 1 = 22 \cdot 45 \text{ lbs.}$$
and area of bucket $= \cdot 7854 \times 24^2$
$$= 452 \cdot 38 \text{ square inches.}$$
$\therefore$ pressure required $= 10155 \cdot 93$ lbs.
$$= 4 \cdot 5 \text{ tons nearly.}$$

214. Find the pressure against an elliptical mud-hole door of a boiler from the following data: pressure of steam 20 lbs. above the atmosphere, diameters of door 10 inches and 8 inches

respectively, and centre of the door 12 feet below the surface of the water in the boiler.

$$\text{Area of door} = \cdot 7854 \times 10 \times 8 = 62 \cdot 832 \text{ square inches.}$$

Again, pressure due to the water : 12 feet. :: 14·75 lbs. : 34 feet.

$$\therefore \text{ pressure} = \frac{12 \times 14 \cdot 75}{34} = 5 \cdot 20 \text{ lbs.}$$

Hence the whole pressure per square inch

$$= (20 + 5 \cdot 2) = 25 \cdot 2 \text{ lbs.}$$

$$\therefore \text{ pressure on door} = 25 \cdot 2 \times 62 \cdot 832$$

$$= 1583 \cdot 3 \text{ lbs.}$$

215. An oval mud-hole door is 11 inches by 8½ inches, and its centre is 8 feet below the surface of the water in the boiler, the load on the safety-valve is 10 lbs.; find the whole pressure on the door. *Ans.* 989·1 lbs.

216. If the centre of a mud-hole door, 12 inches by 9 inches, be 10 feet below the surface of water in the boiler, and the steam have a pressure of 12 lbs. above the atmosphere, find the pressure on the door. *Ans.* 1386 lbs.

217. Should mud-hole doors be fitted on the inside or outside of a boiler? The depth of the water in a boiler is 5 feet, and the pressure of the steam 9 lbs.; what is the pressure on a circular door 7 inches in diameter? *Ans.* 493·4 lbs.

218. The steam-port of an engine, fitted with Seaward's slides, is 2 feet 2 inches by 4½ inches; find the pressure of the slide against the nozzle, the force of the steam being 8 lbs., and that of the uncondensed vapour in the cylinder 2 lbs.

$$8 + 15 = 23 \text{ lbs. (the steam pressure);}$$

$$\text{and } 23 - 2 = 21 \text{ lbs. (the effective pressure).}$$

Also, 2 feet 2 inches = 26 inches,

$$\text{and } 26 \times 4 \cdot 5 = 117 \text{ square inches.}$$

$$117 \times 21 \text{ lbs.} = 2457 \text{ lbs.} = 1 \cdot 1 \text{ tons nearly.}$$

219. The steam-port of an engine, fitted with Seaward's slides, is 2 feet 5 inches by 4¾ inches; find the pressure of the slide

against the nozzle, the pressure of steam being 10 lbs., and that of the uncondensed vapour in the cylinder 4 lbs.

Ans. 2892 lbs.

220. The steam-port of an engine, fitted with Seaward's slides, is 2 feet 6 inches by $4\frac{3}{4}$ inches; find the force requisite to draw the slide over the nozzle, the pressure of the steam being 10 lbs., and of the uncondensed vapour $3\frac{1}{2}$ lbs., the friction being supposed to be $\frac{1}{20}$ of the pressure. *Ans.* 153·18 lbs.

221. Sea-water contains $\frac{1}{33}$d of solid matter, and it is required that the water in a boiler may not contain more than $\frac{4}{33}$ds; what proportion must the quantity blown out bear to the quantity evaporated?

Let x=quantity blown out in a given time,

y=quantity boiled away in same time.

$\therefore x+y$=quantity entering boiler as feed in that time.

$\frac{x+y}{33}$=quantity of foreign matter introduced by these means;

also $\frac{4x}{33}$=quantity blown out.

$$\therefore \frac{x+y}{33}=\frac{4x}{33},$$

$$\text{or } x+y=4x.$$

$$\therefore x=\frac{y}{3},$$

or the quantity blown out is equal to $\frac{1}{3}$d the quantity converted into steam.

222. What ratio must the water blown out of a boiler bear to that evaporated, that the saturation of the boiler may be $\frac{5}{33}$? *Ans.* 1 to 4.

223. What quantity of water must be blown out of a boiler for every 100 gallons boiled off, that the saturation may be $\frac{3}{33}$? *Ans.* 50 gallons.

224. Find the ratio between the quantity of sea-water converted into steam and that blown out, that the brine in the boiler may contain $\frac{3}{33}$ of solid matter. *Ans.* 2 to 1.

225. If 1000 gallons of sea-water be converted into steam, what quantity of brine must be blown out that the boiler may contain water of $\frac{5}{3}$ degree of saturation? *Ans.* 250 gallons.

226. What will be the loss per cent of fuel in the last question, if the pressure of the steam be 10 lbs., and the temperature of the feed-water be 100°?

By Table A, *Marine Engine*, the temperature corresponding to 25 lbs. is 241°;

Hence the water blown out has been raised 141°,

and the quantity of heat expended in producing this is 250×141.

Again, since the heat in steam is 1212°, the heat expended in the steam is 1000×1112;

Hence the whole quantity of heat expended is $1000 \times 1112 + 141 \times 250$,

and that wasted is 250×141.

$\therefore$ the percentage of loss $= \dfrac{141 \times 100}{1112 \times 4 + 141}$

$= 3 \cdot 07$ per cent.

NOTE. The boiling-point is here taken as 241°, which would be correct for fresh water; but with brine the boiling-point would be about 246°, and the loss per cent about 3·2.

227. If the quantity of brine expelled from a boiler loaded to 10 lbs. be $\frac{1}{4}$th that admitted as feed, find the loss per cent in fuel.

Ans. 4·1 per cent.

228. A boiler loaded to 50 lbs. consumes 200 tons of coal in a certain time, and the amount of brine blown out is half the feed; find the amount of fuel wasted. *Ans.* 30·5 tons.

229. The load on the safety-valve of a boiler is 15 lbs.; find the force of the steam when blowing off, if the vessel be heeling over 12°.

The valve will remain closed till the steam has a pressure

$= 15 \cos. 12° = 14 \cdot 67$ lbs.

230. A boiler is loaded to 10 lbs.; what force will the steam have when blowing off, if the ship be heeling over 20°?

Ans. 9·397 lbs.

231. A boiler is loaded to 50 lbs.; what is the greatest force of the steam when the ship is heeling over 15°?

Ans. 48·3 lbs.

232. If a boiler be loaded to 10 lbs., what is the amount of heel in the ship when the pressure of the steam blowing off is $9\frac{1}{2}$ lbs.? *Ans.* 18° 12′.

233. The pressure of steam in a boiler when blowing off is 47 lbs., but the pressure to which the valve is loaded is 50 lbs.; find how much the ship is heeling over. *Ans.* 19° 57′.

234. The injection-orifice of a steamer, at the depth of 12 feet below the level of the sea, being choked up, find what force steam of 15 lbs. pressure will exert to clear it.

The pressure of the water $= \cdot 434 \times 12$

$= 5 \cdot 208$ lbs.

$\therefore$ the available pressure $= 15 - 5 \cdot 2$

$= 9 \cdot 8$ lbs.

235. If the pressure of steam in a boiler be 9 lbs., what force will it have in clearing an injection-orifice at the depth of 10 feet below the surface of the sea? *Ans.* 4·7 lbs.

236. The depth of an injection-orifice is 15 feet below the surface of the sea, and the pressure of steam in the boiler is 9 lbs.; what force will the steam exert to clear the orifice?

Ans. 2·5 lbs.

237. The crank of an engine is 2 feet 6 inches, and the paddle-shaft 12 feet, the distance between the crank-faces was $6\frac{1}{8}$ inches when on the top centre, and $5\frac{7}{8}$ inches when on the bottom centre; how much is the outer end of the shaft depressed?

Ans. ·6 inches.

238. Find the nominal horse-power of the engines of H.M.S. *Termagant*, diameter of cylinder 62 inches, length of stroke 3 feet 6 inches, revolutions per minute 36·5, and number of cylinders four.

$$\text{Horse-power of each cylinder} = \frac{d^2 \times \text{feet per minute}}{6000}$$
$$= \frac{62^2 \times 3{\cdot}5 \times 73}{6000}$$
$$= 163{\cdot}69.$$
$$\text{Hence horse-power required} = 163{\cdot}69 \times 4$$
$$= 654{\cdot}76.$$

239. Find the nominal horse-power of the engines of H.M.S. *Ajax*, the number of cylinders 4, diameter of each 55 inches, length of stroke 2 feet 6 inches, and number of revolutions 45.

Ans. 453·5 horse-power.

240. Find the nominal horse-power of the engines of H.M.S. *Vixen*, diameter of cylinders (two in number) 63 inches, length of stroke 5 feet 3 inches, and revolutions per minute 18.

Ans. 250 horse-power.

241. Find the nominal horse-power of the two cylinder trunk-engines of H.M.S. *Arrogant*, the piston being equivalent to a circular one, whose diameter is 55 inches, length of stroke 3 feet, and number of revolutions 55. *Ans.* 333 horse-power.

242. Find the nominal horse-power of an engine of the following dimensions:

Diameter of cylinder, 55½ inches.
Stroke of piston, 5 feet.
Number of revolutions, 21.

Ans. 107·8 horse-power.

243. Find the diameter of the piston of a steam-engine of 100 nominal horse-power, the load on a circular inch of the safety-valve being 10 lbs., and velocity of the piston 200 feet a minute. *Ans.* 40·6 inches.

244. The boilers of a pair of marine engines evaporate 400 cubic feet of water per hour, the diameter of the piston is 82 inches, and length of stroke 6 feet 9 inches; find the horse-power when the steam is cut off at half-stroke, the number of strokes per minute being 12.

Evaporation for each engine = 200 feet per hour.

$$\therefore s = \frac{200}{60} = 3 \cdot 333.$$

$$v = 12 \times 2 \times 6\tfrac{3}{4} = 162.$$

$$d = 6 \cdot 833 \text{ feet.}$$

Then by Case 2, Rule 1, p. 298, *Marine Engine*,

Log. s =	0·522835	Constant log. =	2·747750
Constant log. =	6·531475	Log. 162 =	2·209515
	0·191730	Log. 6·833 =	·834611
		Log. 6·833 =	·834611
Log. 17620000 =	7·246040		
		Log. 4231000 =	6·626487

$$A = 17620000$$
$$B = 4231000$$
$$\frac{13389000}{33000} = 406.$$

$\therefore$ horse-power required = 812.

245. The boilers of a pair of marine engines evaporate 500 cubic feet of water per hour; the diameter of each piston is 65 inches, and length of stroke 5 feet. If the steam be cut off at two-thirds the stroke, and the number of revolutions of the crank be 18, find the collective horse-power.

Ans. 955 horse-power nearly.

246. Taking the data of question 244, as far as the dimensions of the engine are concerned, and supposing the boilers to evaporate 500 cubic feet of water per hour; find what number of revolutions should be made to give the maximum useful effect, the boilers being loaded to 15 lbs. per inch.

Referring to Case 2, Rule 2, p. 304, *Marine Engine:*

Since pressure of steam = 15 + 15 = 30 lbs.

Then log. p =	1·477121
Constant log. =	0·569982
Log. 111·5 =	2·047103
4·227	
Log. 115·727 =	2·063434
Log. 6·833 =	·834611
Log. 6·833 =	·834611
Log. A =	3·732656

$$\begin{aligned}
\text{Log. } s &= \cdot 619719 \\
\text{Constant log.} &= 5 \cdot 104909 \\
\text{Log. } \frac{l}{p+c} &= \cdot 259594 \\
\text{Log. B} &= 5 \cdot 984222 \\
&\quad 3 \cdot 732656 \\
\text{Log. } 178 \cdot 4 &= 2 \cdot 251566
\end{aligned}$$

$\frac{178 \cdot 4}{6\frac{1}{4} \times 2} = 13 \cdot 2$, number of revolutions required.

247. Taking the data of question 244, find the number of revolutions of the engines to elicit the maximum useful effect, if the boiler be loaded to 10 lbs. *Ans.* 19½ nearly.

248. Find the effective evaporation of the boilers for a pair of engines of 250 collective horse-power, the diameter of the piston being 65 inches, length of stroke 5 feet 2 inches, and number of revolutions per minute 20, when the steam is cut off at half-stroke.

$$5 \text{ feet } 2 \text{ inches} \times 2 \times 20 = 206 \cdot 6 \text{ feet (velocity).}$$
$$65 \text{ inches} = 5 \cdot 416 \text{ feet (diameter).}$$

$$\begin{aligned}
\text{Constant log.} &= 6 \cdot 531475 \\
\text{Table E} &= 0 \cdot 191730 \\
&\quad 6 \cdot 723205
\end{aligned}$$

$$\begin{aligned}
\text{Constant log.} &= 2 \cdot 747750 \\
\text{Log. } 5 \cdot 416 &= \cdot 733679 \\
\text{Log. } 5 \cdot 416 &= \cdot 733679 \\
\text{Log. } 206 \cdot 6 &= 2 \cdot 315132 \\
\text{Log. } 3390000 &= 6 \cdot 530240
\end{aligned}$$

$$\begin{aligned}
&3390000 \\
&4125000 = 125 \times 33000 \\
&7515000
\end{aligned}$$

$$\begin{aligned}
\text{and log. } 7515000 &= 6 \cdot 875929 \\
&\quad 6 \cdot 723205 \\
\text{Log. } 1 \cdot 422 &= \cdot 152725
\end{aligned}$$

$1 \cdot 422 \times 2 = 2 \cdot 844$ cubic feet per minute.

249. Find the effective evaporation of the boilers for a pair of engines of 320 collective horse-power; diameter of piston 64 inches, length of stroke 5 feet 6 inches, number of revolutions per minute 16, when the steam is cut off at $\frac{5}{8}$ths the stroke.

Ans. 3·476 cubic feet.

250. Required the pressure of steam in the cylinder of an engine before expansion, if the steam be cut off at $\frac{3}{4}$ths the stroke, the dimensions of the cylinder being 54 inches diameter, length of stroke 4 feet 4 inches, and number of revolutions 21; the boilers evaporating 3 cubic feet per minute.

Here diameter = 54 inches = 4·5 feet.

Velocity = $4\frac{1}{3} \times 42 = 182$ feet.

Now log. 3 =	·477121	Log. 4·5 =	·653213
Constant log. = 5·104909		Log. 4·5 =	·653213
From Table E =	·096910	Log. 182 = 2·260071	
	5·678940		3·566497

5·678940
3·566497

Log. 129·5 = 2·112443

129·5
4·227

125·273

Log. 125·273 = 2·097951
·569982

Log. 33·7 = 1·527969

Ans. 33·7 lbs.

251. If the boilers of an engine evaporate 250 cubic feet an hour, what will be the pressure of the steam in the cylinder before expansion, its diameter being 70 inches, length of stroke 6 feet, steam cut off at $\frac{3}{8}$ths the stroke, and the number of revolutions of crank 16?

Ans. 52·5 lbs.

252. Find the diameter of the cylinder of an engine to develop 150 horse-power when the steam is cut off at $\frac{1}{8}$ths the stroke, the length of stroke being 5 feet 4 inches, and number of revolutions of the crank 18, if the boilers evaporate 1·2 cubic feet per minute.

Here velocity $= 36 \times 5\frac{1}{3} = 192$ feet.

Log. 1·2 = ·079181
Constant log. = 6·531475
From Table E = 0·133858 + ·002201

Log. 5581000 = 6·746715

5581000
$150 \times 33000 = 4950000$

631000

Log. 631000 = 5·800029 = log. A.

Again, log. 192 = 2·283301
Constant log. = 2·747750

Log. B = 5·031051

Log. A = 5·800029
Log. B = 5·031051

2) ·768978

Log. 2·42 = ·384489

$2 \cdot 42 \times 12 = 29 \cdot 04$ inches. *Ans.*

253. Find the diameter of the cylinder of an engine of 100 horse-power, if the number of revolutions of the crank, when the steam is cut off at $\frac{3}{8}$ the stroke, is 20, the length of stroke being 5 feet, and the evaporation of the boiler 1 cubic foot a minute.

Ans. 5 feet nearly.

254. Having given the diameter of a cylinder 80 inches, the length of stroke 7 feet 10 inches, the number of revolutions of crank 12, and the pressure of steam in the boiler (by the gauge)

15 lbs., before the expansion, which takes place at $\frac{5}{8}$ the stroke; find the requisite evaporating power of the boiler.

Here diameter $= 6 \cdot 666$ feet,

Velocity of piston $= 15 \cdot 666 \times 12 = 188$,

Relative volume (by Table A) corresponding to 30 lbs. $= 882$.

Log. diameter	$= \cdot 823865$	Log. 882	$= 2 \cdot 945469$
Do.	$= \cdot 823865$	From Table E	$= \cdot 170836$
Log. velocity	$= 2 \cdot 274158$	Constant log.	$= \cdot 104909$
Log. A	$= 3 \cdot 921888$	Log. B	$= 3 \cdot 221214$

Log. A $= 3 \cdot 921888$
Log. B $= 3 \cdot 221214$

Log. $5 \cdot 019 = \cdot 700674$

Ans. $5 \cdot 02$ feet nearly.

255. Find the horse-power of the engine mentioned in the last question, assuming the evaporation to be 5 cubic feet an hour.

Log. 5	$= \cdot 698970$	Constant log.	$= 2 \cdot 747750$
Constant log.	$= 6 \cdot 531475$	Log. 188	$= 2 \cdot 274158$
From Table E	$= \cdot 137987$	Log. $6 \cdot 666$	$= \cdot 823865$
		Log. $6 \cdot 666$	$= \cdot 823865$
Log. 23360000	$= 7 \cdot 368432$	Log. 4673000	$= 6 \cdot 669638$

A $= 23360000$
B $= 4673000$

$33{,}000 \overline{)} 18687{,}000$

566

Ans. 566 horse-power.

256. If the before-mentioned engine were so constructed as to cut off the steam at $\frac{3}{8}$ the stroke, and the horse-power were 566, what would be the requisite evaporation (by Rule 3, Case 2, p. 307)?

Constant log. $= 6 \cdot 531475$
From Table E $= \cdot 249443$

$6 \cdot 780918$

Constant log. $= 2 \cdot 747750$
Log. $6 \cdot 666 = \cdot 823865$
Log. $6 \cdot 666 = \cdot 823865$
Log. $188 = 2 \cdot 274158$

Log. $4673000 = 6 \cdot 669638$

4673000
18687000

23360000

Log. $23360000 = 7 \cdot 368473$
$6 \cdot 780918$

Log. $3 \cdot 868 = \cdot 587555$

$\therefore$ evaporation $= 3 \cdot 868$ cubic feet per minute.

257. Lastly, find the pressure of steam in the cylinder before expansion, if the horse-power be 566, and the steam be cut off at $\frac{3}{8}$ the stroke, the evaporation being $3 \cdot 868$.

Log. $3 \cdot 868 = \cdot 587555$
Constant log. $= 5 \cdot 104909$
From Table E $= \cdot 376759$

$6 \cdot 069223$
$3 \cdot 921888$

Log. $140 \cdot 4 = 2 \cdot 147335$

$140 \cdot 4$
$4 \cdot 227$

$136 \cdot 173$

Log. velocity $= 2 \cdot 274158$
Log. diameter $= \cdot 823865$
Do. $= \cdot 823865$

$3 \cdot 921888$

Log. $136 \cdot 173 = 2 \cdot 134177$
Constant log. $= \cdot 569982$

Log. $36 \cdot 66 = 1 \cdot 564195$

Hence it appears that steam of $36 \cdot 6$ lbs., cut off at $\frac{3}{8}$ the

stroke, will develop the same horse-power as steam of 30 lbs. cut off at $\frac{5}{8}$, and that the evaporation (and therefore the consumption of fuel) in the two cases will be as $3 \cdot 868$ to 5.

258. Find the surface of one blade of a propeller whose diameter is 14 feet, pitch 16 feet 6 inches, and length 2 feet 9 inches.

To find the surface of the complete screw:

Circumference of circle, whose diameter is 14 feet,
$= 3 \cdot 1416 \times 14 = 43 \cdot 9824$ feet.

Then if CB (page 317, *Marine Engine*) $= 16\frac{1}{2} = 16 \cdot 5$,
and CA $= 43 \cdot 98$,

$$AB = \sqrt{43 \cdot 98^2 + 16 \cdot 5^2} = 46 \cdot 97.$$

Again, if D be a point bisecting CA,

$$CD = 21 \cdot 99$$

$$\text{and } DB = \sqrt{21 \cdot 99^2 + 16 \cdot 5^2} = 27 \cdot 4$$

$$\therefore CB = 16 \cdot 5$$
$$BD = 27 \cdot 4$$
$$BA = 46 \cdot 9$$

$$3)\overline{90 \cdot 8}$$

$30 \cdot 3$ nearly.

Radius $= 7$

$212 \cdot 1$ square feet in complete screw.

But the portion of screw in the propeller $= \frac{2\frac{3}{4}}{16\frac{1}{2}} = \frac{11}{66} = \frac{1}{6}$,

$\therefore$ the surface required $= \frac{212 \cdot 1}{6} = 35 \cdot 3$ square feet.

259. Find approximately the area of each blade of a screw-propeller, whose diameter is 12 feet, and pitch 16 feet, the length being $\frac{1}{6}$th of the pitch. *Ans.* $27 \cdot 22$ square feet.

260. Find approximately the area of each blade of a propeller whose pitch is 20 feet, and diameter 16 feet, the length being $\frac{1}{8}$th of the pitch. *Ans.* $47 \cdot 2$ square feet.

261. Find the area of the *complete* screw, whose diameter and pitch are given in the previous example.

Ans. 283·2 square feet.

262. The length of a propeller is 2 feet 6 inches, the pitch 20 feet, and the diameter 16 feet; required the area of each blade. *Ans.* 35·4 square feet.

263. The blade of a propeller being one-twelfth of a complete screw, prove that the number of inches in its length is equal to the number of feet in the pitch.

264. The pitch of a screw-propeller is 18 feet, and the diameter 16 feet; find the angle of the screw.

$$\text{Circumference to radius } 8 = 3\cdot1416 \times 16$$
$$= 50\cdot2656$$
$$\text{Tan. } \angle BAC = \frac{BC}{AC} = \frac{18}{50\cdot26}$$
$$\text{Log. tan. } BAC = 10 + \log. 18 - \log. 50\cdot26$$
$$\text{Log. } 18 = 1\cdot255272$$
$$10$$
$$11\cdot255272$$
$$\text{Log. } 50\cdot26 = 1\cdot701222$$
$$\text{Log. tan. } 20°59' = 9\cdot554050$$
$$\therefore \angle BAC = 20°59'$$

265. The pitch of a propeller of H.M.S. *Dauntless* is 18 feet, and the diameter 14 feet 8 inches; find the angle; find also what the angle would be if the diameter were reduced 3 feet.

Ans. 21° 21′ and 26° 11′.

266. Find the angle of a screw-propeller whose pitch is 9 feet, and diameter 8 feet. *Ans.* 19° 42′.

267. Find the angle of a propeller whose pitch is equal to the diameter. *Ans.* 17° 40′.

268. Find the angle of the screw whose thread is 8 feet $4\frac{1}{2}$ inches, and length 3 feet $0\frac{1}{2}$ inch.

(1) Constructing the figure as in page 317, *Marine Engine*, the angle at A (which is the angle required) can be measured by instruments, or

(2) Since $\sin. A = \frac{CB}{BA} = \frac{36 \cdot 5}{100 \cdot 5} = \frac{365}{1005}$

$\therefore$ log. sin. $A = 10 + \log. 365 - \log. 1005$

$= 9 \cdot 560127$

$\therefore A = 21° 17' 45''$.

269. Find the angle of a screw whose thread is 9 feet 5 inches, and length 3 feet 10 inches. *Ans.* 24° 1′.

270. Find the angle of a screw whose thread is 10 feet 7 inches, and length 4 feet 5 inches. *Ans.* 24° 40′.

271. The diameter of a propeller being 14 feet 8 inches, and the angle 21° 17′ 45″, find the pitch.

(1) To find the circumference:

Circumference $= 3 \cdot 1416 \times$ diameter

$= 3 \cdot 1416 \times 176$ inches $= 554 \cdot 7$ inches.

(2) Since pitch = circumference $\times$ tan. $\angle$

$= 554 \cdot 7 \times$ tan. 21° 17′ 45″

Now log. $554 \cdot 7 = 2 \cdot 744044$

log. tan. 21° 17′ 45″ $= 9 \cdot 590842$

$12 \cdot 334886$

10

Log. $216 \cdot 6 = 2 \cdot 334886$

Hence pitch of screw $= 216 \cdot 6$ inches $= 18$ feet $0\frac{1}{2}$ inch.

272. The angle of a screw-propeller is 23° 20′, and the diameter 9 feet; required the pitch. *Ans.* 12 feet $2\frac{1}{4}$ inches.

Also, by aid of Table I.:

Look down the vertical column marked 23° till we come to the horizontal line marked 20′, and where these two intersect we

find the number 1·3551; multiply this by the diameter (9 feet), and the result will be the pitch.

Thus, $1 \cdot 3551 \times 9 = 12 \cdot 1959$

$= 12$ feet $2 \cdot 35$ inches, the pitch required.

273. The angle being 23° 20′ as before, and the diameter 9 feet 7 inches, find the pitch.

Here 9 feet 7 inches $= 115$ inches.

Hence $1 \cdot 3551 \times 115 = 155 \cdot 8365$ inches

$= 12$ ft. $11 \cdot 83$ in., the pitch required.

274. The angle of a screw-propeller being 22° 5′, and the diameter 12 feet, required the pitch. *Ans.* 15·29 feet.

275. What must be the pitch of a screw, to advance 13 knots an hour when making 69 revolutions?

Let x be the pitch.

$69\,x$ = advance per minute;

$\therefore 60 \times 69 \times x =$ do. hour.

But the advance per hour is 6080×13.

$$\therefore 60 \times 69 \times x = 6080 \times 13$$

$$\therefore x = \frac{608 \times 13}{6 \times 69}$$

$$= \frac{304 \times 13}{3 \times 69} = 19 \text{ feet.}$$

276. A ship is required to steam at the rate of 10 knots, and the engine-crank to make 74 revolutions; what must be the pitch of the screw, if an allowance of 20 per cent be made for slip?

Let x = the pitch required,

$74 \times 60 \times x$ = speed of screw in feet per hour,

6080×10 = speed of ship in feet per hour.

$$\therefore \frac{74 \times 60 \times x - 60800}{74 \times 60 \times x} = \frac{20}{100} = \frac{1}{5}$$

$$\therefore 4 \times 74 \times 60 \times x = 60800 \times 5$$

$$x = \frac{304000}{74 \times 60 \times 4} = 17 \cdot 1 \text{ feet.}$$

277. Find the pitch of a screw which shall propel a ship at

the rate of 9 knots when driven by engines whose cranks make 56 revolutions per minute, the allowance for slip being 25 per cent. *Ans.* 21$\frac{5}{7}$ feet.

278. Find the pitch of a screw to propel a ship at the rate of 11 knots when driven by engines whose cranks make 100 revolutions per minute, the allowance for slip being 30 per cent. *Ans.* 15·9 feet.

279. The number of revolutions of a propeller is 80 per minute, and the pitch of the screw 15 feet; find the slip per cent when the speed of the ship is 9 knots.

Since the number of feet in a knot = 6080

$\therefore$ the speed of the ship per hour = 6080×9

and the speed per minute = $\frac{6080 \times 9}{60}$ feet

= 912 feet.

Again, speed of screw = $80 \times 15 = 1200$ feet.

Hence slip of screw = $\frac{1200 - 912}{1200}$

= $\frac{288}{1200}$

and slip per cent = $\frac{288}{12} = 24$.

280. A screw-ship's engines, fitted with multiple-gearing, make 31 revolutions per minute; the multiple is 2·3, the pitch of the screw 18 feet, and the rate of the ship 10 knots; find the slip in knots, and the amount per cent.

Ans. 2·663 knots, or 21·04 per cent.

281. The pitch of a screw is 18 feet, the number of revolutions of the engine-crank 30, and the multiple of the screw-gearing $2\frac{1}{2}$ to 1; find the slip per cent, if the speed of the ship be 10 knots. *Ans.* 25 per cent.

282. The engines of H.M. Yacht *Fairy* make 42 revolutions per minute, and the pitch of the screw is 6 feet 9 inches; find the number of revolutions of the screw for each revolution of the cranks, that the speed of the screw may be 14 knots.

Ans. 5 to 1.

283. The pitch of a screw-propeller is 11 ft. 6 in., the number of revolutions of crank 104 per minute, and the slip 19·2 per cent; required the speed of the ship. *Ans.* 9·53 knots.

284. Given the length of a screw 2 feet, the thread of ditto 4 feet 10½ inches, diameter of ditto 5 feet 8 inches; find the area of each blade, angle, and pitch of the screw.

Also, if the revolutions of the cranks of the engines be 29·6 per minute, and the multiple of the screw-gearing 5·16 to 1; find the slip of the screw per cent, the speed of the ship being 8·955 knots.

Ans. Area of blade, 9·3 square feet; angle of screw, 24° 13′; pitch of screw, 8 feet 1 inch; slip per cent, 25·7.

285. From the following data, find the same quantities as in the previous example.

	ft.	in.		
Length	1	6	Revolutions of crank	60
Thread	3	11½	Multiple of gearing	2 to 1
Diameter	8	6	Speed of ship	11 knots.

Ans. Area of each blade, 11·1 square feet; angle, 22° 16′; pitch, 11 feet; slip per cent, 15·5 nearly.

286. What is the most economical speed for a ship steaming against a 4-knot tide?

Ans. Since the greatest economy will result if the ship's rate be $\frac{5}{2}$ × the rate of the opposing tide, the speed required should be 6 knots.

287. A steam-ship, short of fuel, is bound for a port 150 knots distant; but a current sets her from the port at the rate of 3 knots; at what rate should she steam, and how long will she be in reaching it? *Ans.* 4½ knots; 4⅓ days.

288. What is the most economical speed against a stream running uniformly at the rate of 5 knots? *Ans.* 7½ knots.

289. If the speed of a vessel be 9 knots, with 350 horse-power; what must be the power to give her a speed of 11 knots?

Let x be the horse-power required; then, since the horse-power varies as the cube of the speed, we shall have

$$x : 350 :: 11^3 : 9^3$$

$$\therefore x = \frac{350 \times 1331}{729} = 639 \text{ horse-power.}$$

290. If the speed of a ship, when using only 3 boilers, be 7 knots, what speed might be expected with 4 boilers?

The consumptions in the two cases may be represented by the numbers 3 and 4 respectively; $\therefore$ if x be the speed required,

$$3 : 4 :: 7^3 : x^3$$

$$\therefore x^3 = \tfrac{4}{3} \times 343$$

$$= 457 \cdot 333$$

$$x = 7 \cdot 7 \text{ knots.}$$

291. If a ship's 4 boilers drive her at 10 knots, what will be her rate with 2 boilers? *Ans.* 7·937 knots.

292. With 560 horse-power, a steamer's speed is 10 knots; what will be her speed if the horse-power be increased to 800? *Ans.* 11·28 knots.

293. The rate of a steamer being 6 knots with a flue-boiler, it was found that when a new tubular boiler was substituted the rate was 7 knots; compare the consumptions of fuel *per day* in the two cases, also the consumptions in a voyage between two given places.

(1) For the consumption *per day*:

Let C be the daily consumption with the old boiler, and C′ with the new boiler;

Then $C : C' :: 6^3 : 7^3$

$:: 216 : 343$

or as 11 : 18 nearly.

(2) For the consumption between two given places:

$$C : C' :: 6^2 : 7^2$$

$$:: 36 : 49.$$

294. If 400 tons of coal are sufficient for a given voyage at the rate of 10 knots, at what rate must the vessel steam to make 300 tons last out the voyage? *Ans.* 8·6 knots.

295. If 180 tons of coal suffice for a voyage of 800 miles at the rate of 9 knots, how many tons will be required for 1200 miles at the rate of 7 knots?

Let x be the number required;

Then, since the number of tons varies as the distance $\times$ the square of the speed, we have

$$x : 180 :: 1200 \times 7^2 : 800 \times 9^2$$
$$\therefore x = 163\tfrac{1}{3} \text{ tons.}$$

296. If 80 tons of coal suffice for a voyage of 1000 miles at the rate of 8 knots, how many tons will be required for 1500 miles at the rate of 10 knots? *Ans.* 187·5 tons.

297. A steamer, at her highest speed, which is 10 knots, consumes 1 ton of coals an hour, and when 800 knots from the port to which she is bound, finds she has only 45 tons of fuel remaining; at what rate must she proceed to enable her to reach the port without the aid of sails?

At the consumption of 1 ton an hour, the quantity she would require at 10 knots would be 80 tons;

Hence, if x be the rate at which she must steam, we have

$$45 : 80 :: x^2 \times 800 : 10^2 \times 800$$
$$:: x^2 : 10^2$$
$$\therefore 80x^2 = 45 \times 10^2$$
$$x^2 = \frac{45 \times 100}{80}$$
$$= \frac{5}{4} \times 45$$
$$= \frac{225}{4}$$
$$= 56 \cdot 25$$
$$\therefore x = \sqrt{56 \cdot 25}$$
$$= 7 \cdot 5 \text{ knots.}$$

298. From Gibraltar to Malta, being 1100 miles, a steamer going at full speed (11 knots) consumed 250 tons of coal; on her return-voyage, with a view to economy, she proceeded at 8 knots; what was her consumption? *Ans.* 132 tons.

299. A steam-vessel's floats being too deeply immersed, the number of revolutions of the crank was 14 per minute, and the speed of the ship 6 knots; after they were reefed the number of revolutions increased to 20; find the speed of the ship.

By Art. 362, *Marine Engine*, we see that in such cases the speed of the engine varies as the cube of the speed of the ship.

Let x be the speed of the ship after reefing the paddles;

$$\text{Then } x^3 : 6^3 :: 20 : 14$$

$$\text{or } x^3 = \frac{216 \times 20}{14}$$

$$\therefore x = \sqrt[3]{308 \cdot 571}$$

$$= 6 \cdot 7 \text{ knots.}$$

300. The revolutions of the cranks of a tug-vessel's engines were 16, and the rate was 4 knots; the multiplying gear was then set in action, and the number of revolutions was 20; find the rate of the vessel.

Since the revolutions of the crank vary as the cube of the speed of the ship; $\therefore$ if V be the required speed of the ship:

$$V^3 : 4^3 :: 20 : 16$$

$$V^3 = \frac{64 \times 20}{16} = \frac{5}{4} \times 64$$

$$= 80$$

$$\therefore V = \sqrt[3]{80}$$

$$= 4 \cdot 3.$$

301. The cranks of an engine, when the vessel is towing, make 12 revolutions, and the rate is 4 knots; the multiple-gearing is then put in action, and the cranks make 20 revolutions; find the speed of the vessel and the multiple used.

The speed of the vessel is, by the former principles, 4·74 knots.

Again, to find the multiple used, we must consider that the speed of the wheel is increased in the ratio of $4 \cdot 74 : 4$;

$$\therefore \text{as } 4 : 4 \cdot 74 :: 12 : \frac{4 \cdot 74 \times 12}{4}$$

$$= 14 \cdot 22.$$

The wheel, therefore, makes $14 \cdot 22$ revolutions; but the engine-cranks make 20 revolutions, hence the multiple of the gearing must be as $20 : 14 \cdot 22$; or as $1 \cdot 4 : 1$.

EXAMINATION PAPERS

ON

SUBJECTS CONNECTED WITH THE STEAM-ENGINE.

No. 1. A.

1. What is the diameter of a valve containing 100 square inches?

2. The pressure on a safety-valve is 10 lbs. per square inch; how much is it on each circular inch?

3. Give a description of the steam-engine in use before the time of Watt, with an account of his improvements.

4. What is meant by the "parallel motion"? Investigate the necessary proportions among the various rods, that the piston of a side-lever engine may move vertically.

5. Are the delivery-valve and foot-valve *absolutely* necessary to the performance of an engine? If a *condensing* engine were upwards of 30 feet from the ground-floor of a building, could the air-pump be altogether dispensed with?

6. What is meant by the terms *cushioning* and *clearance*? Does the amount of clearance above the piston of a side-lever engine usually increase or diminish as the engine wears?

7. Are the eccentrics of marine-engines fixed on the shaft in the same manner as for land-engines? Explain the method of obtaining the back motion in marine-engines.

8. How is the scale of the barometer-gauge graduated? What error is introduced by having the scale fixed, as is usually the case? To what extent will a thermometer, having its bulb inserted in the condenser, supply the place of a barometer-gauge?

9. Give a sketch of a feed-valve box and pipes, and name the valves. Is it necessary to have an air-vessel to the exit-pipe when an overflow-valve is fitted to the box?

10. The extreme diameter of a paddle-wheel is 28 feet, and the breadth of the boards 2 feet 3 inches; the number of revolutions 16; and it is found that the speed of the ship is the same as that of the upper edge of the boards; find the speed of the ship, and show that if the rate of the wheel were estimated, supposing the water to act at one-third the distance from the upper edge of the board, the slip would be 6 per cent approximately.

11. The pitch of one of the blades of a screw-propeller is 20 feet 8 inches, and the number of revolutions is 42. If there were no slip, what would be the speed of the ship in knots? Again, the pitch of the other blade being 21 feet 7 inches, if the speed of the ship be that already found, what would be the slip per cent, reckoning from the latter blade?

12. Give a sketch and explanation of the oscillating-engines.

No. 1. B.

1. Name and give a short description of the gear connected with marine-boilers requiring the attention of the engineer.

2. A circular tube is replaced by 4 circular tubes of the same total volume; show that the heating-surface is thereby doubled.

3. If a circular inch be allowed as the area of a safety-valve for every 20 square feet of heating-surface, what must be the

diameter of a valve for a boiler whose heating-surface is 1000 square feet?

4. Give a description of the reverse-valve. If kept in its place by its weight, and the material be brass, what must be its thickness that it may open when the pressure of the steam within the boiler is $1\frac{1}{2}$ lbs. below that of the atmosphere? the weight of a cubic foot of brass being 525 lbs.

5. It is frequently the practice to keep the safety-valves open while the fires are banked up; is this advisable?

6. Why is the hydrometer an imperfect instrument without the thermometer? What is the meaning of the number 55° placed on the back of the scale of the hydrometer in use in the navy, and what objections are there to the adoption of so low a number?

7. A safety-valve of 9 inches diameter is replaced by an annular-valve of 6 inches (outer) diameter; what must be the inner diameter of the latter that it may have the same total opening for steam?

8. A boiler is loaded to 10 lbs.; what force will the steam have when blowing off if the vessel heel over 20 degrees?

9. If great inconvenience be experienced from ashes, &c., escaping from the funnel, how would you endeavour to remedy it?

10. If one engine of a ship were disabled, what difficulty might you expect when endeavouring to work with the remaining one, and how would you get over the difficulty?

11. Show how to find the proper length of the eccentric-rod of an engine.

No. 1. C.

1. What is meant by the nominal horse-power of an engine, and how is it determined for paddle-wheel vessels?

2. Find the nominal horse-power of an engine of the following dimensions:

Diameter of cylinder, $55\frac{1}{2}$ inches;
Stroke of piston, 5 feet;
Number of revolutions, 21.

3. Find the effective evaporation of the engine whose dimensions are given in question 2, if the horse-power be supposed to be 107·4.

4. From Gibraltar to Malta, being 1100 miles, a steamer going at full speed (11 knots) consumed 250 tons of coal; on her return-voyage, with a view to economy, she proceeded at 8 knots; what was the consumption?

5. What is the most economical speed against a stream running uniformly at the rate of 5 knots?

6. Explain the construction and principle of the indicator.

7. In what cases would you consider it necessary to take an indicator-diagram from the top and bottom of the cylinder; and how would you, from these diagrams, get the work developed in the up and down strokes respectively?

8. Give an outline of a normal-slide diagram; and show, by a corresponding diagram, the alteration that would take place if the slide-rod were shortened.

9. Show, by slide-diagrams, the advantage to be gained by expansive working over throttling, when making the same number of revolutions.

10. The diameters of the *Penelope's* cylinders are $91\frac{1}{2}$ inches, and length of stroke 6 feet 8 inches; assuming the number of revolutions to be 16, and the indicator-pressure 16 lbs., find the horse-power of both engines.

11. What kind of diagram will be obtained by shutting off the injection-water?

12. If the gab-lever of an engine be shortened, what alteration will take place in the indicator-diagram?

No. 2. A.

1. Find the area of the section of a steam-funnel 5 feet 3 inches in diameter, and the number of square feet of iron in it, if its length be 20 feet.

2. There are 2 valves; the diameter of one is 2 inches less than that of the other, and the sum of their areas is the same as that of a valve of 10 inches diameter; find their dimensions.

3. Describe the single-acting engine. What kind of engine is commonly used in steam-vessels?

4. Give a description of the long D-slide; and give a sketch of one having lap on the steam-sides and negative lap on the exhaust-sides.

5. What is the use of the cylinder escape-valves? The steam-pressure of a boiler is increased from 8 to 10 lbs.; how much must the height of the lead cylindrical weight on the valve be increased, its diameter being the same as that of the valve, and a cubic foot of lead 710 lbs.?

6. Explain the method of working slides by means of eccentrics, and give the names of the gear connecting the intermediate shaft with the slide-rod.

7. What advantage is supposed to exist in working slides by cams over the more usual plan by eccentrics?

8. Find the area of rubbing-surface in a steam-cylinder 91½ inches in diameter, the stroke of the piston being 6 feet 8 inches.

9. A screw-ship's engine makes 31 revolutions per minute, the multiple is 2·3, pitch of the screw 18 feet, rate of the ship 10 knots; find the slip in knots, and the amount per cent.

10. The lever of the overflow-valve of a feed-valve box is 12 inches long, and the valve-spindle is 4 inches from the fulcrum; the weight at the end of the lever is 10 lbs., and diameter of the valve 4 inches; find the weight on each square inch.

11. Give a description of Hall's condenser.

12. Find the load on the air-pump bucket of a steam-engine when 16 feet below the level of the water outside the ship, the pressure of the atmosphere being 14¾ lbs., and that of the steam within the condenser 2½ lbs. (a cubic foot of sea-water weighing 64 lbs.)

13. Give a sketch and explain the working of the engines called "trunk-engines."

No. 2. B.

1. The dimensions of a boiler are 20 feet by 14, and the height of the water in it 11 feet; it contains 200 tubes of 3 inches (external) diameter, and 6 feet long, and 3 fire-places, each being 6 feet by 2 feet 6 inches, and 4 feet high; what is the quantity of water in the boiler (the fire-box, &c., not being taken into account.)?

2. There are 3000 tubes in a set of marine-boilers, their *external* diameter being 3 inches, thickness of metal ¼ inch, and length 6 feet; find the amount of power developed, 16 square feet being equivalent to one horse-power.

3. Give a description of the apparatus by which a boiler is prevented from bursting and collapsing. How is the pressure of the steam in the boiler ascertained? Can the same dependence be placed on an old gauge as on a new one?

4. Describe the communication-valve, and explain its use. If working with 3 boilers instead of 4, what would be the effect of opening all the communication-valves?

5. If the snifting-valve of an engine do not fit close, what will be the pressure on the foot-valve of the air-pump, its dimensions being 2 feet by 15 inches, and the condenser-gauge at 20 inches?

6. Why will a fire burn more briskly on first lighting with

only a small quantity of water in the boiler? What is meant by "banking up" the fires? When should it be practised: and if done, should the safety-valves be open or closed?

7. How would an engineer prevent danger to his boiler in case the blow-off cocks were set fast? Does the amount to be blown off depend on the time, or on the rate of the vessel?

8. What is the advantage of expansive working over throttling, and what advantage is gained from each?

9. If one engine become disabled, what should be done that the ship may be propelled with the remaining one?

10. How is the slide of an engine placed in the middle of its stroke (when adjusting the slides)?

11. How is it ascertained whether the piston of an engine is steam-tight?

No. 2. C.

1. If 22 square inches of the piston be considered equivalent to one horse-power: what is the power of two engines, the diameter of each cylinder being 91 inches?

2. What determines the nominal horse-power of an engine? What evaporating power should a boiler have for a pair of engines of 560 *collective* horse-power, the diameter of the cylinder being 88 inches, length of stroke 5 feet 9 inches, and making 17 revolutions per minute?

3. Find approximately the area of the blade of a screw-propeller; the diameter being 12 feet, the pitch 16 feet, and the length one-sixth of the pitch.

4. With 560 horse-power, a steamer's speed is 10 knots; what will be her speed if the horse-power be increased to 800?

5. Describe the indicator. What kind of steam-engine does it most resemble?

6. Diagrams were taken from above and below the piston of

an engine, and it was observed that the steam-line of the former was much contracted and the vacuum-line spread out, while the opposite defects were exhibited in the latter; how can this be remedied?

7. The gab-lever of an engine being shortened, what effects will this have on the indicator-diagram?

8. Find the horse-power of an engine whose mean steam-pressure is 13·2 lbs., and vacuum-pressure 2·7 lbs.; the length of stroke being 4 feet 3 inches, diameter of cylinder 41 inches, and the number of revolutions 23 per minute; the usual allowance being made for friction.

9. The blade of a propeller being $\frac{1}{12}$th of a complete screw, prove that the number of inches in the length gives the number of feet in the pitch.

10. Explain the nature of the slide-diagram. How does this enable us to discover the amount of maximum opening of the port?

11. The length of stroke of a steam-engine is 5 feet 6 inches, and the boiler-pressure 12 lbs. above the atmosphere; the steam is cut off after the piston has traversed two feet; find the pressure of the steam in the cylinder when it opens to the exhaust, which is two inches before the piston arrives at the end of the stroke.

No. 3. A.

1. Mention the distinguishing features of the atmospheric, single-acting, and double-acting engines; what kind of engine is generally fitted to steam-vessels, and what kind is best suited for land-carriage?

2. Describe the long D slide, and show how it is worked by the eccentric. How is the packing of the slide at the upper and lower ends lubricated?

3. Explain the meaning of the terms *cushioning, lead,* and *lap.* On what is the lead made to depend?

4. In a given engine, the depth of each slide-face was 1 inch greater than the port, there was $\frac{1}{4}$th of an inch lap on each exhaust side, and $\frac{1}{8}$th of an inch was allowed for lead; how much was the lower port open to the exhaust when the piston was at the top of its stroke?

5. Describe the barometer-gauge in common use. Why is the stop-cock closed before blowing through?

6. The *weather* barometer on one occasion was 30 inches, and at another was 29 inches; in which case will the pressure of the steam on the piston be the greatest?

7. What are the two kinds of instruments used in propelling vessels through the water? Could they both be used entirely immersed? What are the modifications of Morgan's paddle-wheel on the common wheel?

8. What proportion should the diameter of a paddle-wheel bear to the radius of the crank; and what is considered a good immersion?

9. The diameter of a safety-valve is 10 inches; find the difference in the total pressure of the steam to raise the valve if it be 9 lbs. per circular inch above what it would be if it were 9 lbs. per square inch.

10. The bottom of a steam-boiler is 18 feet below the level of the sea; find the requisite steam-pressure to force the water of the boiler through the blow-out pipe.

11. Why are tubular boilers superseding the use of flue-boilers in steam-vessels; and explain why they contain a smaller quantity of water?

12. In land-engine boilers, a vertical tube containing a float and communicating with the external air passes through the crown of the boiler into the water; if the steam-pressure in the boiler be 8 lbs. per square inch, find how high the water will

stand in the tube; and if the lower end of the tube be 3 feet below the level of the water, what is the steam-pressure when air begins to enter the boiler: will the boiler thus fitted require a reverse-valve?

13. Give a sketch of a blow-valve and snifting-valve; and show why these valves require no springs or weights to keep them in their seats.

No. 3. B.

1. How is it ascertained whether blow-out cocks are closed, and how can you make sure that the throttle-valves are partially open?

2. What is necessary to the good combustion of fuel beyond a plentiful supply of air; and why for this reason is it advantageous not to have more water in the boiler on first lighting the fires than is absolutely necessary?

3. Would you recommend, in a case of priming, that the safety-valves should be kept open?

4. If funnel-stays were to break while getting up the steam, to what cause would this be owing? and would the accident be likely to happen in a vessel in which they had but little spread?

5. If the water become very low in the boiler, why is it dangerous to pump in a fresh supply too suddenly; what method would you adopt in such a case?

6. What advantage attends the use of water in lubricating hot bearings? when other plans fail, would you recommend the use of cold water for that purpose?

7. Supposing the shaft of a side-lever paddle-engine were to be raised on account of the too great immersion of the wheels, what parts of the engine would require lengthening?

8. If it be found that the piston strikes the bottom of the cylinder, what should be done to lessen the defect, for a time, without stopping?

9. A shot enters a boiler 2 feet below the surface of the water within it; the safety-valve is 10 inches in diameter, and the diameter of the iron weight attached to it is 12 inches, its length being 18 inches; with what force will the water begin to issue from the orifice (weight of a cubic foot of iron 440 lbs.)?

10. Show how to blow through when no blow-valves are fitted. After very cold weather, would you expect any inconvenience in blowing through if the engine had not been used for some days?

11. Find the length of the connecting-rod, eccentric-rod, and length of stroke of an engine.

No. 3. C.

1. How much water will be required to fill a cylinder whose diameter is 60 inches, and length 6 feet, with steam 40 times per minute; the volume of the steam being 1200 times that of the water from which it was formed?

2. A steamer at 10 knots consumes 25 tons a day; after steaming for 3 days at 8 knots she goes 200 knots further at $7\frac{1}{2}$ knots; what is the whole quantity consumed?

3. A steamer is 500 miles distant from the port she wishes to reach, and has coal enough to carry her over 300 miles. The port bears due west from her; will she be able to get within *steaming* distance by *sailing* on a N W by W course?

4. Wishing to construct an engine of 200 horse-power, what must be the diameter of the cylinder that the length of stroke may be 5 feet 8 inches, and the number of revolutions 21; the effective evaporating power of the boiler being 3 cubic feet a minute?

5. Define the slip of the screw. The pitch of a screw-propeller is 6 feet 8 inches; the number of revolutions of the engine

42; multiple 5 to 1; rate of ship 12 knots: what is the slip per cent?

6. What must be the pitch of a screw to propel a ship at the rate of 10 knots, allowing 75 revolutions per minute, and estimating the slip at 10 per cent?

7. Explain the use and construction of the indicator. If it be found that the divisions on the scale indicating the steam-pressure are too large, how can this be remedied without re-graduating it?

8. What kind of diagram would be obtained at the upper and lower ends respectively of the cylinder if the slide-rod were shortened?

9. The mean indicated pressure of steam from above the piston was 14·9 lbs., and the vacuum-pressure 3·2 lbs.; and the corresponding pressures from below were 15·4 and 2·7 lbs.; what were the mean effective pressures per square inch during the up and down stroke respectively?

10. What alteration would be produced in the upper and lower indicator-diagrams if a portion of the lap were taken from the exhaust side of the upper slide-face and the same amount added to the lower exhaust side?

11. Find the quantity of water evaporated by a boiler if the terminal indicator-pressure be 16 lbs. (the corresponding relative volume being 1573); the diameter of the piston being 3 feet 6 inches, length of stroke 4 feet, and number of revolutions 25.

No. 4. A.

1. Distinguish between a double-acting and single-acting engine. Why is the parallel motion dispensed with in the latter kind of engine?

2. The outer circumference of a paddle-wheel is to travel

over 11½ knots an hour, and the number of revolutions of the engine per minute is 16; find its diameter.

3. Explain the method adopted for keeping the piston and piston-rods of steam-engines steam-tight.

4. Why are the steamers of H.M. navy still fitted with blow-valves, although the steam in the boiler enables the engines to start without a vacuum in the condenser?

5. Find the force requisite to open a blow-valve 5 inches in diameter, the steam-gauge standing at 10 inches, and the condenser-gauge at 28 inches.

6. The diameter of a steam-cylinder being 64 inches, what must be the diameters of the cylinders of a double-cylinder engine of the same power to supply its place, the speed of the engine being unaltered?

7. What is the advantage of using two eccentrics instead of the double-eccentric, in case the boiler should prime or the injection-cock be left open?

8. Describe the locomotive slide. Is this slide economical in steam?

9. The travel of a slide is 14 inches, depth of the port 6 inches, and the slide is short on the exhaust side ¼ inch when at the middle of its stroke; how far does the slide go below the lower edge of the port, on the exhaust side, at the extreme of its stroke?

10. Show how a helical surface is generated. What is meant by a screw of increasing pitch? How is the pitch of a screw measured?

11. There are 20 fire-places, each 2 feet 6 inches wide; height, 4 feet 6 inches; height of the bridge from the bottom of the ash-pit, 2 feet 6 inches; what is the total area over the bridge per horse-power, the horse-power of the boilers being 580?

12. Describe the steam-gauge of a boiler. The legs of a steam-gauge are of the same area and equal length, each being 10 inches. Can this gauge be used for a boiler loaded to 12lbs.?

No. 4. B.

1. Describe the oscillating engines. Why is the stuffing-box deeper in these engines than in those that have fixed cylinders?

2. The side-lever of a steamer's engine was broken, and the rods bent from water getting into the cylinders; is it probable that this took place from the condenser having been previously hot?

3. The diameter of a snifting-valve is 8½ inches; what is the pressure on it to keep it close, the condenser-gauge standing at 27 inches?

4. Should mud-hole doors be fitted on the inside or on the outside of a boiler? The depth of the water in a boiler is 5 feet, and the pressure of the steam 9 lbs.; what is the pressure on a circular door 7½ inches in diameter?

5. Show how to adjust the parallel motion of a side-lever engine.

6. The single eccentric is fitted with a weight to balance it; what would be the effect on the slide if it were to become detached?

7. Show how an engine could be blown through if no blow-valves were fitted.

8. The overflow-valve of a feed-pump is 4 inches in diameter, the length of lever is 16 inches, and the valve-spindle 4 inches from the fulcrum; what weight must be attached to the end of the lever to balance the pressure of steam in the boiler when working at 11 lbs.? would you make the actual weight more or less than this?

9. The safety-valve of a steam-boiler is 9½ inches in diameter, and the iron weight connected with it is a cylinder whose diameter is 12 inches, and depth 20 inches; required the pressure to which the boiler is loaded—1st, per square inch, 2d, per circular inch, the specific gravity of iron being 442.

10. If you were apprehensive that a steam-piston was leaky, how would you discover it without removing the cylinder-cover?

11. If one of the paddle-wheels of a steamer were damaged by shot or other causes, would you work the remaining paddle with one engine, or with both?

12. Show how to put the crank of an engine on the centre; and explain the method adopted for setting the stops on the eccentrics.

13. Do engines with horizontal cylinders require any special attention whilst the vessel is lying in harbour?

14. Why is a three-bladed screw-propeller sometimes used instead of the usual two-bladed one?

No. 4. C.

1. Find the nominal horse-power of the engines of H.M.S. *Ajax;* the number of cylinders 4, diameter of each 55 inches, length of stroke 2 feet 6 inches, and number of revolutions 45.

2. The effective evaporation of an engine is 1 cubic foot a minute; the steam is cut off at half-stroke, and the mean velocity of the piston is 150 feet a minute; what must be the diameter of the piston to develop 100 horse-power?

3. A steamer when towing makes 12 revolutions, and the rate is 4 knots; the multiple-gearing is then put in action, and the crank makes 20 revolutions; find the speed of the vessel and the multiple used.

4. The cranks of a pair of engines are 3 feet in length, and

the length of the connecting-rods 8 feet; find at what angles the cranks should be placed that the one engine may be at the upper dead centre when the other is at half-stroke.

5. Find the surface of a screw-propeller whose diameter is 10 feet, and pitch 11 feet; the portion used being $\frac{1}{8}$th of a whole convolution.

6. The pitch of a screw-propeller is 11 feet 6 inches, the number of revolutions 104 per minute, and the slip 19·2 per cent; required the speed of the ship.

7. State why an indicator-diagram taken from an engine working paddles is of much better form when taken at moorings than when the vessel is free to move. Sketch both diagrams.

8. Show how to find separately the value of the steam and vacuum pressures of a piston-diagram. In what cases is it important to separate the results?

9. Sketch a high-pressure diagram. How is the steam from the cylinder of a condensing-engine got rid of when working at high pressure?

10. Show by an indicator-diagram the advantages of working expansively over throttling.

11. Sketch a friction-diagram, and show how it is to be obtained.

12. Sketch a normal slide-diagram, and also a slide-diagram with the eccentric-stop advanced.

No. 5. A.

1. Give an account of the principal discoveries of Watt, and the advantages derivable from them.

2. Describe the blow-valve and snifting-valve, and show why the former is not so important now as it formerly was. For what reason is it still retained?

3. The diameter of a blow-valve is 4 inches, and the steam-gauge stands at 15 inches; what force is required to lift it before and after a vacuum has been created in the condenser, the barometer-gauge in the latter case standing at 26 inches?

4. Explain what is meant by the terms *lap*, *lead*, *cushioning*, and *expansion*, as applied to steam-engines.

5. Give a short description of the common D slide, the short D, the locomotive slide, and Seaward's slide. What kind of slide is used for double-cylinder engines?

6. The diameter of the piston-rod of a screw-ship's engine is $\frac{1}{10}$th of the diameter of the cylinder; find it, having given the area of the cylinder 2376 square inches.

7. The length of a gab-lever is 10 inches, and the travel of the slide is 12 inches; find the travel of the slide if the gab-lever be shortened an inch.

8. Describe the common vacuum-gauge; and explain why there is usually a small error in the reading-off.

9. The upper side of an equilibrium-valve is 11 inches in diameter, and the lower side 10 inches; find the force requisite to lift it if the steam-gauge stand at 15, and the atmosphere be acting between the upper and lower beating-surfaces.

10. Give a full description of Maudslay's double-cylinder engines. The condenser of these engines is said to have become encrusted with salt on the upper part; explain the cause of this.

11. The pressure on a steam-piston being two tons, find how much will be left for the propulsion of the ship after deducting what is necessary for working the air-pump; the force requisite to lift the bucket being 3 cwt., the length of the side-lever 18 feet, and the distance from the main centre to the point of connection of the air-pump side-rod $4\frac{1}{2}$ feet.

12. Explain how the reverse motion is obtained in engines fitted for paddle-wheel and screw-vessels respectively.

13. The lever of the overflow-valve of a feed-valve box is 9 inches long, and the spindle is $2\frac{1}{2}$ inches from the fulcrum; the weight at the end of the lever is 12 lbs., and the diameter of the valve $2\frac{1}{2}$ inches; find the pressure per inch necessary to lift the valve.

No. 5. B.

1. What are the advantages and disadvantages of tubular boilers? and what are the peculiarities of marine-boilers when contrasted with land-boilers?

2. How is the supply of water for the boilers maintained—

(*a.*) Before the steam is up;

(*b.*) While steaming;

(*c.*) While the engines are stationary?

3. What is meant by the grate-surface of a boiler? If one square foot be allowed for each horse-power, how much will be necessary for boilers to supply a pair of cylinders each of 90 inches diameter; the piston moving at the rate of 236 feet a minute?

4. What is the use of the reverse-valve? If the valve be a brass cylinder 4 inches long, what will be the pressure tending to collapse the boiler when the valve begins to act; the weight of a cubic foot of brass being 525 lbs.?

5. If running in for the land at night-time, would you throttle the steam, or use the expansion-gear?

6. The diameter of a snifting-valve is $8\frac{1}{2}$ inches; what is the amount of pressure to keep it close when the condenser-gauge stands at 28 inches?

7. What disadvantages attend having a large quantity of water in boilers on first lighting the fires, and what are the advantages of having a large quantity when under steam?

8. How would you attempt to check the inconvenience arising from hot ashes escaping from the top of the funnel?

9. If the bottom of your condenser were leaky, how would you endeavour to remedy the defect when at sea?

10. If you had taken possession of an enemy's steamer, how would you ascertain that the cocks were closed, and the throttle-valve partially open, before the fires were lighted?

11. How would you proceed to work with one engine, if the other were disabled?

12. If the water in the boiler-gauge were unsteady, how could you correct the defect?

No. 5. C.

1. Find the nominal power of a pair of *trunk*-engines, the diameter of the cylinders being 5 feet, and the space occupied by the trunk being equivalent to a circle of 2 feet 6 inches diameter; having given the velocity of the pistons 220 feet a minute.

2. The effective evaporation of a set of boilers is 2·5 cubic feet a minute, the diameter of the piston 5 feet 4 inches, the velocity of ditto 190 feet a minute; the steam is cut off at $\frac{2}{5}$ds the stroke; find the initial pressure of steam in the cylinder.

3. What is the most economical speed for a steamer against a four-knot stream?

4. A steamer consumes 3 tons an hour when steaming at the rate of 10 knots; what will she consume at 8 knots? If *all* the boilers be used in each case, how would you, in the latter, prevent the steam from blowing off?

5. Find the pitch of a screw whose angle is 18° 40′, and diameter 12 feet; what will be its length if the portion used be $\frac{1}{8}$th of a whole convolution?

6. Describe the indicator, and explain its uses.

7. The steam-pressure, before expansion, is 10 lbs. above the atmosphere; the steam is cut off at $\frac{3}{4}$ths the stroke; the exhaust commences at $\frac{19}{20}$ths, the cushioning at $\frac{9}{10}$ths, and there is no lead. Represent the diagram you would expect to obtain.

8. Why is the lead of an engine not observable in an ordinary low-pressure diagram? How can you arrange so as to exhibit it more clearly in the same engine?

9. What kind of diagram would you expect to get by attaching the string to the cross-head of the slide?

10. The initial pressure in a steam-cylinder 10 feet 9 inches high is 45 lbs., and the steam is cut off at 3 feet 6 inches; find the terminal-pressure.

11. What sort of diagram would you obtain by shutting off the *injection-water*? If you saw a loop formed in the right-hand corner, what would be your inference with respect to the grade of expansion you were using?

No. 6. A.

1. A screw-ship is to be fitted with engines of 1000 collective horse-power, and the total surface of the pistons is to be 21,000 square inches, the number of cylinders being 4; find the diameter of each.

2. Explain the principle on which expansive working of steam is said to be advantageous. If the length of the stroke of an engine be 3 feet 6 inches, and the steam be cut off at 2 feet 4 inches, find the initial-pressure, the terminal-pressure being 14 lbs.

3. Describe the Cornish double-beat valve.

4. Describe the common condenser-gauge of an engine. Show that the scale is always incorrect if it be graduated to inches. The mean steam-pressure on a piston being 7 lbs. above

the atmosphere, and the mean vacuum-pressure 12 lbs., what is the force exerted on a piston of 55 inches diameter; and what would have been the force if the engine had worked without condensation of the steam?

5. A paddle-wheel 9 feet in diameter is fitted with 15 boards; find the space between them.

6. Give definitions of the following terms with reference to a screw-propeller: *angle, pitch, length, diameter,* and *thread.*

7. The pitch of a screw is 16 feet, and diameter 18 feet; the number of revolutions is 90 per minute; find the rate of the screw in knots, and the distance traversed by a point in the circumference of the screw.

8. A double-acting air-pump is substituted for a single-acting one of 2 feet diameter; what must be the diameter of the former?

9. The area of a brine-valve is $\frac{1}{4}$th that of the feed; if the diameter of the latter be $4\frac{1}{2}$ inches, find that of the former.

10. What force applied to the extremity of a crank at right angles to it will do the same work as a mean pressure of 4 tons acting on the piston throughout the up and down stroke?

11. If the cock of the feed-pipe in connection with the boiler be closed, what becomes of the water forced up by the feed-pump?

12. The brine-pump of a boiler being choked, how is the brine to be got rid of; the steam-gauge indicating 3 lbs., and the upper surface of the water being 9 feet below the level of the sea?

No. 6. B.

1. A pair of double-cylinder engines are substituted for single-cylinder engines of 75 inches diameter; if the total surface of the piston and length of stroke be the same in both cases, com-

pare the surfaces of the cylinders exposed to the friction of the pistons.

2. An air-pump is to be fitted with an annular-valve, in lieu of the common round valve whose diameter is 20 inches. If its outer diameter be 16 inches, what must be its inner diameter to allow the same escape for the water?

3. The injection-orifice of a steamer 3 feet below the level of the water is closed with *ice;* can it be got rid of with steam of atmospheric pressure?

4. Find the pressure to keep close a Kingston's valve which is 6 inches in diameter, and 24 feet below the level of the sea.

5. Why is it advisable not to get under weigh directly the steam has reached the required pressure? If obliged to do so, what two methods might be adopted to keep the steam up in the boilers; and which of these would you prefer adopting if steaming through an intricate channel?

6. If the fires were banked up, what advantage would you gain by allowing the safety-valves to remain closed?

7. If the amount of saline matter in salt water be $\frac{1}{35}$d, find what proportion the quantity of brine blown out should bear to the quantity of water converted into steam to keep the water at $\frac{4}{35}$ds.

8. If the engines be not working at full speed, would you consider it desirable to use all the boilers or not? State your reasons.

9. It is generally supposed that advantage would be gained by working the engines of steam line-of-battle ships with a worse vacuum than in vessels of lighter draught; on what grounds does this rest? Would you, under any other circumstances, adopt this plan?

10. For what reason is it always advantageous to work expansively with leaky slides?

11. Show how to adjust the parallel motion of a side-lever engine.

12. How can the "blowing through" be effected where no blow-through valves are fitted?

No. 6. C.

1. If the steam generated by a boiler be not sufficient to supply the engines at the pressure to which the boiler is loaded, at the normal speed of the engines, show clearly that an advantage would in such case be gained by using the expansion-gear.

2. Find the nominal power of the 4-cylinder engines of H.M.S. *Edinburgh;* diameter of cylinders 55 inches; length of stroke 2 feet 6 inches; number of revolutions 52.

3. Find the evaporation of a set of boilers to supply the cylinders of the above engines when not working expansively.

4. Find the slip of the screw of the French steamer *Faon;* number of revolutions 40; multiple of gearing 4 to 1; pitch of screw 7·7 feet; and speed of ship 12 knots.

5. The number of revolutions of a screw-propeller is 30, and the multiple of the gearing $2\frac{1}{2}$ to 1. Find the pitch of the screw if 25 per cent be allowed as slip, and the speed of the ship be 10 knots.

6. The speed of H.M.S. *Highflyer,* of 250 horse-power, being $9\frac{1}{2}$ knots, what must be the power that her speed may be increased a knot?

7. The crank of an engine is 3 feet, and the connecting-rod 8 feet; find the angle the crank will make with the vertical when the engine is at half-stroke.

8. For what purposes is the indicator applied to the cylinders of steam-engines? Trace the peculiarities in the curve arising from expansion of the steam, duction, cushioning, and lead.

9. Having given a normal piston-diagram, show what change

in its form will take place if the injection-water be shut off; or secondly, if the steam be throttled.

10. What kind of diagram would you obtain if the eccentric (or gab) lever of the engine be too long?

11. How can it be ascertained by the aid of a slide-diagram if the stop of the eccentric is properly adjusted?

HINTS

FOR THE

SOLUTION OF THE EXAMINATION PAPERS.

No. 1. A.

1. Since area of a circle $= \cdot 7854 \times \text{diameter}^2$

$$\therefore \text{diameter}^2 = \frac{\text{area}}{\cdot 7854}$$

$$= \frac{100}{\cdot 7854}$$

$\therefore$ diameter $= 31 \cdot 8$ inches.

2. Area of each circular inch $= \cdot 7854$ square inches.

$\therefore$ pressure on valve $= 7 \cdot 854$ lbs.

3. See *Marine Engine*, ed. 3, art. 72.

4. Ditto ditto arts. 81 and 97.

5. Ditto ditto arts. 102 and 106.

6. Ditto ditto arts. 92 and 113.

The clearance above the piston diminishes because the side-rods and connecting-rod are shortened by wear.

7. See *Marine Engine*, art. 121.

8. Ditto ditto arts. 135, 136; and *Indicator*, &c. p. 45, note.

9. Ditto ditto art. 142.

The air-vessel is not necessary for slow-working engines; but there is an advantage in fitting it to engines of great speed.

10. Now 28 feet − 4 feet 6 inches = 23 feet 6 inches = $\frac{47}{2}$ feet, the inner diameter.

$$\frac{47}{2} \times \frac{3 \cdot 1416 \times 16 \times 60}{6080} = 11 \cdot 6 = \text{speed of ship in knots.}$$

Again, $28 - 3 = 25$ feet.

$$\therefore \text{slip} = \frac{25 - \frac{47}{2}}{25} = \frac{50 - 47}{50} = \frac{3}{50} = \frac{6}{100}$$

and hence slip per cent = 6.

11. Here 20 feet 8 inches $= 20\frac{2}{3} = \frac{62}{3}$.

$$\frac{62}{3} \times \frac{42 \times 60}{6080} = 8 \cdot 5 \text{ knots} = \text{speed of ship.}$$

Again, 21 feet 7 inches = 259 inches,

20 feet 8 inches = 248 inches;

$$\therefore \text{slip of screw} = \frac{259 - 248}{259} = \frac{11}{259}$$

$$\text{and slip per cent} = \frac{1100}{259} = 4 \cdot 2 \text{ per cent.}$$

12. See *Marine Engine*, art. 173, for paddle-wheels.

Ditto ditto art. 177, for screws.

No. 1. B.

1. See *Marine Engine*, art. 183.

2. Let d_1 and d_2 be the respective diameters of the tubes,

and l = length of each;

s_1 and s_2 the surfaces.

Then $\cdot 7854 \times d_1^2 \times l = 4 \times \cdot 7854 \times d_2^2 \times l$,

or $d_1 = 2d_2$.

Again, $s_1 = 3 \cdot 1416\ d_1 l$,

and $s_2 = 4 \times 3 \cdot 1416\ d_2 l$;

$$\therefore \frac{s_1}{s_2} = \frac{d_1}{4d_2} = \frac{d_1}{2d_1} = \frac{1}{2}$$

$$\therefore s_2 = 2s_1.$$

3. No. of circular inches in valve $= \frac{1000}{20} = 50$;

$\therefore$ diameter of valve $= \sqrt{50} = 7 \cdot 07$ inches.

4. See *Marine Engine*, art. 206.

Also, since a cubic foot of brass weighs 525 lbs.

$\therefore$ a cubic inch weighs $\frac{525}{1728}$ lbs.

Let d = diameter of valve,

x = thickness of metal of ditto.

Then $\cdot 7854 \times d^2x$ = volume of brass,

and $\frac{525}{1728} \times \cdot 7854 d^2x$ = weight of ditto in lbs.

But pressure upwards $= 1 \cdot 5 \times \cdot 7854 d^2$;

$\therefore \frac{525}{1728} \times \cdot 7854 d^2x = 1 \cdot 5 \times \cdot 7854 d^2$;

or $x = \frac{1 \cdot 5 \times 1728}{525} = 4 \cdot 9$ inches.

5. See *Marine Engine*, art. 237.

6. Ditto ditto art. 244.

7. Since the steam escapes at the edges of the valves, the sum of the circumferences of the annular-valve must equal the circumference of the common valve; $\therefore$ if x be its inner diameter,

$$3 \cdot 1416 \times x + 3 \cdot 1416 \times 6 = 3 \cdot 1416 \times 9;$$

or $x + 6 = 9$;

$\therefore x = 3$.

8. By *Marine Engine*, art. 251, the pressure of the steam will

$= 10 \times \cos 20°$

$= 9 \cdot 39$ lbs.

9. See *Marine Engine*, art. 254.

10. Ditto ditto art. 284.

11. Ditto ditto art. 309.

No. 1. C.

1. See *Marine Engine*, art. 347.

2. Velocity of piston $= 5 \times 2 \times 21 = 210$ feet per minute,

and horse-power $= \frac{d^2 \times \text{feet per minute}}{6000}$

$= \frac{55 \cdot 5^2 \times 210}{6000}$

$= \frac{3070 \cdot 25 \times 21}{600} = 107 \cdot 4.$

3. Constant log. = 2·747750
Log. diameter = 0·664642
Ditto = 0·664642
Log. 210 = 2·322219

Log. 2510000 = 6·399253

Useful effect × 33000 = 3544200
2510000

6054400

Log. 6054400 = 6·781755
Constant log. = 6·510286

Log. 1·87 = ·271469

Ans. 1·87 cubic feet.

4. Let C be the quantity consumed.

Then $C : 250 :: 8^2 \times 1100 : 11^2 \times 1100$;

or $C = \frac{250 \times 8^2}{121}$

$= \frac{16000}{121} = 132 \cdot 2.$

5. The ship should steam half as fast again as the opposing current.

6. See *Indicator*, &c. p. 7.

7. Ditto p. 42.

8. Ditto pp. 21 and 28.

9. Ditto p. 34.

10. Area of piston $= \cdot 7854 \times 91 \cdot 5^2$

Pressure on ditto $= 16 \times \cdot 7854 \times 91 \cdot 5^2$

Length of double stroke $= 13\frac{1}{3}$ feet $= \frac{40}{3}$;

$\therefore$ effect per minute $= \frac{40 \times 16}{3} \times 16 \times \cdot 7854 \times 91 \cdot 5^2$,

and horse-power $= \frac{40 \times 16 \times 16 \times \cdot 7854 \times 91 \cdot 5^2}{3 \times 33000}$

$= 680 \cdot 1.$

11. See *Indicator*, &c. p. 50.

12. Ditto p. 46.

No. 2. A.

1. Since 5 feet 3 inches $=5\cdot25$ feet,
and area of section of funnel $=\cdot7854\times5\cdot25^2$
$=21\cdot6$ square feet.
Also number of square feet of iron $=3\cdot1416\times5\cdot25\times20$,
$=330$ square feet.

2. Let x=diameter of smaller valve,
$x+2$=diameter of larger ditto;
$$\therefore\ x^2+(x+2)^2=10^2$$
$$\text{or } 2x^2+4x+4=100$$
$$x^2+2x=48$$
$$x^2+2x+1=49$$
$$x+1=7$$
$$\left.\begin{aligned} x&=6\\ \text{and } x+2&=8\end{aligned}\right\}\text{the required diameters.}$$

3. See *Marine Engine*, ed. 3, arts. 78, 87.

4. Ditto ditto arts. 89, 115.

5. Ditto ditto art. 96.

Let h=the required additional height of the cylinder,
A=area of the base.

Now since $\frac{710}{1728}$=weight of a cubic *inch* of lead,

$\frac{710}{1728}Ah$=additional weight of the lead,
$=2\times A$

(because the pressure has been increased 2 lbs. per inch);

$$\therefore\ h=\frac{2\times1728}{710}=4\cdot8 \text{ inches.}$$

6. See *Marine Engine*, art. 119.

7. Ditto ditto art. 141.

8. Diameter of cylinder $= 91 \cdot 5$ inches;

$\therefore$ circumference of ditto $= 3 \cdot 1416 \times 91 \cdot 5$,

and friction-surface $= 80 \times 3 \cdot 1416 \times 91 \cdot 5$

$= 159 \cdot 6$ square feet.

9. Revolutions of screw per minute $= 2 \cdot 3 \times 31$

$= 71 \cdot 3$

and advance of screw per minute $= 71 \cdot 3 \times 18$

$= 1283 \cdot 4$ feet,

and advance of screw per hour $= 1283 \cdot 4 \times 60$

$= 77004$ feet

$= \frac{77004}{6080}$ miles

$= 12 \cdot 66$;

$\therefore$ slip of screw in knots $= 12 \cdot 66 - 10$

$= 2 \cdot 66$ knots;

and slip per cent $= \frac{2 \cdot 66}{12 \cdot 66} \times 100 = 21$.

10. The power of the lever $= \frac{12}{4} = 3$;

$\therefore$ pressure of weight on valve $= 10 \times 3 = 30$.

Also, area of valve $= 3 \cdot 1416$ square inches;

$\therefore$ weight on each square inch $= \frac{30}{3 \cdot 1416}$

$= 9 \cdot 5$ lbs.

11. See *Marine Engine*, art. 98.

12. Since a cubic foot of sea-water weighs 64 lbs.

$\therefore$ pressure of 1 foot on a square inch $= \frac{64}{144}$

and $\therefore$ pressure of column 16 feet high $= \frac{64}{144} \times 16 = 7 \cdot 11$ lbs.

But pressure of atmosphere $= 14 \cdot 75$

and pressure of water $= 7 \cdot 11$

Downward pressure $= 21 \cdot 86$

Upward pressure $= 2 \cdot 50$

Hence load on square inch of bucket $= 19 \cdot 36$.

13. See *Marine Engine*, art. 180.

No. 2. B.

1. Contents of water space in boiler $= 20 \times 14 \times 11 = 3080$ cubic feet;

space occupied by tubes $= \frac{\cdot 7854 \times 3^2 \times 72 \times 200}{1728}$

$= 58 \cdot 8$ cubic feet;

space occupied by fire-places $= 3 \times 6 \times 2 \cdot 5 \times 4 = 180$ cubic feet;

$\therefore$ quantity of water $= 3080 - 58 \cdot 8 - 180 = 2841 \cdot 2$ cubic feet.

2. Diameter of heating-surface of each tube $= 3 - \frac{1}{2}$ in. $= 2\frac{1}{2}$ in.

Length of tube $= 72$ inches;

$\therefore$ surface of tubes $= 3 \cdot 1416 \times 2 \cdot 5 \times 72 \times 3000$

$= 11781$ square feet;

$\therefore$ horse-power required $= \frac{11781}{16} = 736.$

3. See *Marine Engine*, arts. 191, 198, and 207.

4. Ditto ditto arts. 209, 230.

5. Area of valve $= 24 \times 15 = 360$ square inches,

and pressure per inch $= 10$ lbs.;

$\therefore$ total pressure $= 360 \times 10 = 3600$ lbs.

$= 1 \cdot 6$ tons.

6. See *Marine Engine*, art. 31.

7. Ditto ditto art. 250.

8. Ditto ditto art. 126.

9. Ditto ditto art. 284.

10. Ditto ditto art. 308.

11. Ditto ditto art. 338.

No. 2. C.

1. Area of each piston $= \cdot 7854 \times 91^2$

$= 6503 \cdot 9.$

Total piston area $= 13007 \cdot 8;$

$\therefore$ horse-power $= \frac{13007 \cdot 8}{22} = 591 \cdot 26.$

2. See *Marine Engine*, art. 347.

Also, since stroke $=5$ feet 9 inches;

$\therefore$ velocity of piston $=5$ „ $9\times2\times17=195\cdot5$ feet.

Hence by Rule 3, p. 306:

Constant log. $=2\cdot747750$

Log. $7\cdot333=\ \cdot865282$

Log. $7\cdot333=\ \cdot865282$

Log. $195\cdot5=2\cdot248534$

Log. $5271000=6\cdot721848$

5271000

$18480000=$ useful effect.

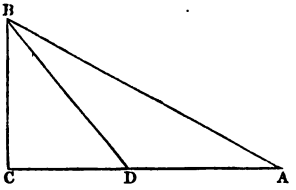
23751000

Log. $23751000=7\cdot375664$

Constant log. $=6\cdot510286$

Log. $7\cdot334=\ \cdot865378$

$\therefore$ evaporation $=7\cdot334$ cubic feet.



3. Let BC be the length of the screw;

AB the thread;

AC the corresponding portion of the circumference of the complete screw.

Then, since circumference $=3\cdot1416\times12=37\cdot6992$ feet,

$$\therefore AC=\frac{37\cdot6992}{6}=6\cdot2832.$$

$$\text{Again, } BC=\frac{16}{6}=2\cdot666;$$

$$\therefore \text{ since } AB=\sqrt{AC^2+BC^2}$$

$$=\sqrt{6\cdot2832^2+2\cdot666^2}$$

$$=6\cdot82;$$

also, if AC be bisected in D,

$$CD=3\cdot1416;$$

$$\therefore BD=4\cdot11.$$

Hence, taking a mean of BC, BD, and BA,

$$\begin{array}{r} BC=2\cdot66 \\ BD=4\cdot11 \\ BA=6\cdot82 \\ \hline 3)13\cdot59 \\ \hline 4\cdot53 \end{array}$$

and $4\cdot53\times6=27\cdot18$ square feet.

4. Since the horse-power varies as the cube of the speed;

$\therefore$ if x be the speed required,

$$x^3 : 10^3 :: 560 : 800$$

$$\therefore x=11\cdot2 \text{ knots.}$$

5. See *Indicator and Dynamometer*, ed. 2, p. 7.

The instrument resembles an atmospheric engine.

6. See *Indicator*, &c. pp. 25-27.

7. Ditto p. 46.

8. Mean effective pressure $=13\cdot2\text{ lbs.}-2\cdot7\text{ lbs.}=10\cdot5$ per sq. inch,

velocity of piston $=4$,, $3\times2\times23=195\cdot5$ feet;

$$\therefore \text{ horse-power } =\frac{\cdot7854\times41^2\times10\cdot5\times195\cdot5}{33000}$$

$$=70\cdot2.$$

9. Since the blade is $\frac{1}{12}$th that of a complete screw,

the length is $\frac{1}{12}$th that of the pitch;

and $\therefore$ the number of inches $\times12=$ the inches in the pitch.

Consequently, if we divide this again by 12, we have the number of feet in the pitch;

Or the number of inches in the length = the number of feet in the pitch.

10. See *Indicator*, &c. p. 21.

11. Distance traversed by steam $=5\text{ ft. }6\text{ in.}-2\text{ in.}=5\text{ ft. }4\text{ in.}=64$ in.

pressure before expansion $=12+15=27$,

distance traversed before expansion $=24$ inches;

$\therefore$ pressure at the instant exhaustion commences

$$=\frac{24}{64}\times27$$

$$=\frac{3}{8}\times27=\frac{81}{8}=10\cdot12 \text{ lbs.}$$

No. 3. A.

1. See *Marine Engine*, arts. 77-80.

2. Ditto ditto arts. 89, 101, and 119.

3. Ditto ditto arts. 113, 114.

4. Lap on steam side = whole excess − lap on exhaust
$= 1 - \frac{1}{4} = \frac{3}{4}$ inches.

Now, when the piston is at the top of stroke the slide is $\frac{1}{8}$-inch open; hence it has been raised

$\frac{3}{4} + \frac{1}{8}$ inches $= \frac{7}{8}$ inches;

consequently the exhaust at lower port is open

$\frac{7}{8} - \frac{1}{4}$ inch $= \frac{5}{8}$ inch.

5. See *Marine Engine*, art. 134.

The stop-cock of the gauge is closed before blowing-through, otherwise the pressure of steam in the condenser would drive the mercury from the cup into the engine-room.

6. The pressure of steam on the piston is that shown by the steam-gauge + the pressure of the atmosphere, and therefore the pressure in the former case would be ·5 lbs. per inch greater than in the latter.

7. The screw-propeller and the paddles. The former should be wholly immersed; but the latter must be only partially in the water. See art. 145.

8. See *Marine Engine*, art. 145 (note), and art. 153.

9. (1) Area of 10-inch valve in circular inches $= 10^2 = 100$;
$\therefore$ pressure on valve $= 9 \times 100 = 900$ lbs.

(2) Again, area of 10-inch valve in square inches
$= \cdot 7854 \times 10^2 = 78 \cdot 54$;

$\therefore$ pressure on valve $= 78 \cdot 54 \times 9 = 706 \cdot 86$ lbs.

$\therefore$ difference of pressure $= 900 - 706 \cdot 86 = 193 \cdot 14$ lbs.

10. The pressure at the depth of 34 feet is the same as that of the atmosphere, viz. 14·75 lbs.

ft. lbs. ft.
$\therefore$ as 34 : 14·75 :: 18 : 7·8 lbs.

Hence the pressure by the gauge must be above 7·8 lbs.

11. See *Marine Engine*, art. 184.

12. (1) As $14{\cdot}75^{\text{lbs.}} : 34^{\text{ft.}} :: 8^{\text{lbs.}} : 18{\cdot}44^{\text{ft.}}$, the height of water in the tube.

(2) As $34^{\text{ft.}} : 14{\cdot}75^{\text{lbs.}} :: 3^{\text{ft.}} : 1{\cdot}3^{\text{lbs.}}$, the pressure below the atmosphere when the air enters the boiler.

13. See *Marine Engine*, arts. 74 and 90.

No. 3. B.

1. See *Marine Engine*, art. 240.
2. Ditto ditto art. 30.
3. Ditto ditto art. 231.
4. Ditto ditto art. 220.
5. Ditto ditto art. 257.
6. Ditto ditto art. 268.
7. The eccentric-rod and the connecting-rod.
8. See *Marine Engine*, art. 339.
9. Pressure of water $= \frac{14{\cdot}75}{34} \times 2 = {\cdot}8$ lbs.

Also, weight of safety-valve weight $= \frac{{\cdot}7854 \times 12^2 \times 18 \times 440}{1728}$

But area of valve $= {\cdot}7854 \times 10^2$;

$\therefore$ pressure of steam per inch $= \frac{12^2 \times 18 \times 440}{10^2 \times 1728}$

$= 6{\cdot}6$ lbs.

and $\therefore$ the pressure of issuing water $= 6{\cdot}6 + {\cdot}8$

$= 7{\cdot}4$ lbs. per square inch.

10. See *Marine Engine*, arts. 341 and 342.
11. Ditto ditto arts. 303 and 309.

No. 3. C.

1. Volume of the cylinder $= {\cdot}7854 \times 5^2 \times 6$ cubic feet;

$\therefore$ quantity of steam per minute $= {\cdot}7854 \times 5^2 \times 6 \times 40$;

and ditto of water forming the steam $= \frac{{\cdot}7854 \times 5^2 \times 6 \times 40}{1200}$

$= {\cdot}7854 \times 5$

$= 3{\cdot}927$ cubic feet.

2. Let C be the consumption per day at the rate of 8 knots.

Then $C : 25 :: 8^3 : 10^3$;

$$\therefore C = \frac{8^3 \times 25}{10^3} = \frac{64}{5} \text{ tons,}$$

and in 3 days the consumption will be $\frac{192}{5} = 38{\cdot}4$ tons.

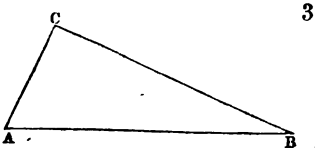
Again, if C^1 be the consumption while going 200 knots at $7\frac{1}{2}$ knots per hour;

Then, since her consumption is 25 tons while going 240 knots at 10 knots an hour, we shall have

$$C^1 : 25 :: 7{\cdot}5^2 \times 200 : 10^2 \times 240;$$

$$\therefore C^1 = \frac{25 \times 7{\cdot}5^2 \times 200}{10^2 \times 240} = 11{\cdot}72,$$

and $C + C^1 = 38{\cdot}4 + 11{\cdot}72 = 50{\cdot}12$ tons.



3. Let A be the port,
B the place of the steamer,
BC her course; $\angle ABC = 33° 45'$.
From A draw AC at right angles to BC.

Then AC is the shortest distance from BC to A;

and $AC = AB \text{ sin. } 33° 45'$

$= 277{\cdot}8.$

Hence she will get within steaming distance.

4. By Rule 5, Case 1, p. 309:

$$\begin{array}{rl} \text{Log. } 3 = & \cdot 477121 \\ \text{Const. log.} = & 6{\cdot}510286 \\ \text{Log. } 9714000 = & 6{\cdot}987407 \\ 6600000 = & \text{useful effect.} \\ \hline 3114000 & \end{array}$$

$$\begin{array}{rl} \text{Log. } 238 = & 2{\cdot}376577 \\ \text{Const. log.} = & 2{\cdot}747750 \\ & \hline 5{\cdot}124327 = \text{log. B.} \end{array}$$

$$\text{Log. } 3114000 = 6{\cdot}493319 = \text{log. A.}$$

$$\begin{array}{r} 5{\cdot}124327 \\ \hline 2)1{\cdot}368992 \\ \hline \cdot 684496 \end{array}$$

$$\text{Log. } 4{\cdot}836 =$$

$\therefore$ diameter required $= 4{\cdot}836$ feet.

5. See *Marine Engine*, art. 161.

$$\text{Pitch of screw} = 6\tfrac{2}{3} \text{ feet} = \tfrac{20}{3} \text{ feet.}$$

$$\text{Advance of screw per hour} = \tfrac{20}{3} \times 42 \times 5 \times 60$$
$$= 20 \times 14 \times 5 \times 60$$
$$= 84000 \text{ feet;}$$

$$\text{also, rate of ship} = 12 \times 6080 \text{ feet in same time;}$$

$$\therefore \text{ slip per cent} = \frac{84000 - 12 \times 6080}{84000} \times 100$$
$$= 13 \text{ per cent.}$$

6. Let p = the pitch required.

Then advance of screw per hour $= 60 \times 75$,

and advance of ship in same time $= 10 \times 6080$;

$$\therefore \frac{60 \times 75 \times p - 10 \times 6080}{60 \times 75 \times p} = \frac{10}{100} = \frac{1}{10}$$

$$\text{or } 4500\,p - 60800 = 450\,p;$$

$$\therefore 405\,p = 6080$$

$$p = 15 \text{ feet.}$$

7. See *Indicator*, &c. pp. 7-9.

If the divisions on the scale are too large, the power of the spring must be relaxed.

8. See *Indicator*, &c. p. 27.

9. Mean pressure in down-stroke $= 14{\cdot}9 - 2{\cdot}7$ lbs.
$= 12{\cdot}2$ lbs.

and mean pressure in up-stroke $= 15{\cdot}4 - 3{\cdot}2$ lbs.
$= 12{\cdot}2$ lbs.

10. See *Indicator*, &c. pp. 25 and 27.

11. Volume of the cylinder $= {\cdot}7854 \times (\frac{1}{2})^2 \times 4$.

50 volumes of cylinder = steam used per minute.

$$= 50 \times {\cdot}7854 \times (\tfrac{1}{2})^2 \times 4,$$

and $\therefore$ quantity of water used $= \frac{50 \times {\cdot}7854 \times (\frac{1}{2})^2 \times 4}{1573}$

$= 1{\cdot}223$ cubic feet.

No. 4. A.

1. See *Marine Engine*, art. 80.

2. Rate of wheel in feet per hour $= 11 \cdot 5 \times 6080$.

$$\frac{6080 \times 11 \cdot 5}{60 \times 16} = 72 \cdot 83 \text{ feet per minute.}$$

$$\frac{72 \cdot 83}{3 \cdot 1416} = 23 \cdot 1, \text{ diameter in feet.}$$

3. See *Marine Engine*, art. 91.

4. Ditto ditto art. 76.

5. Area of valve $= \cdot 7854 \times 25$,

$10 + 15$ lbs. $= 25$ lbs.

$25 - 1 = 24$ lbs.

Then force required $=$ area $\times 24 = 471 \cdot 2$ lbs.

6. The advantage of two eccentrics over the double eccentric consists in the facility it gives the engineer in throwing them out of gear whenever water gets into the cylinder.

7. See *Marine Engine*, art. 110.

Half the travel of the slide $= 7$ inches,

$7 - 6 + \frac{1}{4} = 1\frac{1}{4}$ inches below the port.

8. See *Marine Engine*, art. 157.

9. Area over each bridge $= 5$ square feet;

$\therefore$ total area $= 100$ square feet.

$$\frac{100}{580} = \frac{5}{29} \text{ area per horse-power in sq. ft.}$$

$$= \frac{5 \times 144}{29} \text{ square inches}$$

$$= 24 \cdot 8 \text{ square inches.}$$

10. See *Marine Engine*, art. 198.

The gauge described in this example cannot be used, because the mercury will be driven out when the pressure of the steam exceeds 10 lbs.

No. 4. B.

1. See *Marine Engine*, arts. 173 and 177.

2. Ditto ditto art. 224.

3. Pressure on square inch of valve $=\frac{27}{2}=13\cdot5$ lbs.

and area of valve $=\cdot7854\times8\cdot5^2$

$=56\cdot7451$ sq. in.;

$\therefore$ pressure on valve $=56\cdot7451\times13\cdot5$

$=766\cdot05$ lbs.

4. See *Marine Engine*, art. 331.

Pressure of water in boiler at centre of mud-hole door $\Big\}=2\cdot17$ lbs.

and $\therefore$ pressure on door per square inch . . . . . $\Big\}=9+2\cdot17=11\cdot17$ lbs.

Also area of valve $=44\cdot1787$ square inches.

Hence pressure on door $=44\cdot1787\times11\cdot17=493\cdot47$ lbs.

5. See *Marine Engine*, art. 331.

6. The slide would fall in the casing when the stops on the eccentric and shaft were in such a position that they could separate; and the slide would be useless, because it would admit steam at the wrong time.

7. See *Marine Engine*, art 341.

8. Area of valve $=4^2\times\cdot7854=12\cdot56$ square inches,

pressure of steam on valve $=11\times12\cdot56$

$=138\cdot16$ lbs.;

hence the required weight $=\frac{138\cdot16}{4}=34\cdot54$ lbs.

9. Area of valve $=\cdot7854\times9\cdot5^2=70\cdot88$ square inches;

volume of weight $=\cdot7854\times12^2\times20$

$=2261\cdot8$ cubic inches;

and $\therefore$ weight $=\frac{2261\cdot8\times442}{1728}$

$=578\cdot13$ lbs.

Hence pressure per square inch $=\frac{578\cdot13}{70\cdot88}=8\cdot15$ lbs.

Also, since the number of circular inches is $90\cdot25$,

$\therefore$ pressure per circular inch $=\frac{578\cdot13}{90\ 25}=6\cdot4$ lbs.

10. See *Marine Engine*, art. 338.
11. Ditto ditto art. 278.
12. Ditto ditto art. 307.
13. Ditto ditto art. 343.
14. Ditto ditto art. 343.

No. 4. C.

1. Horse-power of each cylinder $= \frac{\cdot 7854 \times 55^2 \times 7 \times 5 \times 45}{33000}$

$= 112 \cdot 4$;

horse-power of four cylinders $= 449 \cdot 6$.

2. Log. $1 = 0 \cdot 000000$

Constant log. $= 6 \cdot 531475$

From Table E $= \cdot 191730$

Log. $5287000 = 6 \cdot 723205$

5287000

$3300000 = 100 \times 33000$

1987000

Log. $1987000 = 6 \cdot 298198 =$ log. A.

Log. $151 = 2 \cdot 178977$

Constant log. $= 2 \cdot 747750$

Log. B $= 4 \cdot 926727$

$6 \cdot 298198$

$4 \cdot 926727$

$2)1 \cdot 371471$

Log. $4 \cdot 85 = \cdot 685735$

$4 \cdot 85 \times 12 = 58 \cdot 2$ inches. *Ans.*

3. Since by art. 362 the speed of the engine varies as the cube of the speed of the ship,

$\therefore$ if v be the speed of the ship after the multiple-gearing has been set in action,

we have $12 : 20 :: 4^3 : v^3$;

$$\therefore v^3 = \frac{20 \times 4^3}{12} = 106 \cdot \dot{6}$$

$v = 4 \cdot 74$ knots.

Also, for revolutions of the wheel we must have

$4 : 4 \cdot 74 :: 12 : 14 \cdot 22$;

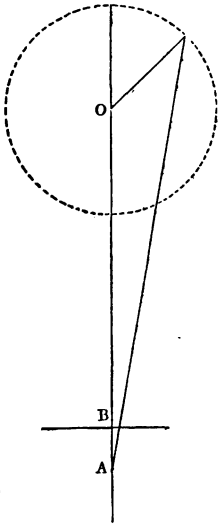
hence the multiple used is $\frac{20}{14 \cdot 22} = \frac{1 \cdot 4}{1}$

4. Referring to *Marine Engine*, art. 364:

Let $a=3$ feet,

$c=8$,

and $x=3$.



Then $\text{Cos.}\frac{\theta}{2}=\sqrt{\frac{19\times 3}{12\times 8}}=\sqrt{\frac{19}{32}}$

Log. 19= ·278754

Log. 32= ·505150

$2)\overline{1}\cdot 773604$

$\overline{1}\cdot 886802$

10

$\text{Log. Cos.}\frac{\theta}{2}=9\cdot 886802$

$\therefore \frac{\theta}{2}=$ 39° 35′ 45″

$\theta=$ 79° 11′ 30″ $=\angle$ POA;

$\therefore 180-\theta=100°\ 48'\ 30''$.

5. Length of screw $=\frac{11}{8}=1\cdot 375$ feet,

also base of $\triangle = 3\cdot 1416\times\frac{10}{8}=3\cdot 926$ feet;

$\therefore$ hypothenuse $=\sqrt{1\cdot 375^2+3\cdot 926^2}=4\cdot 11$ feet,

and line bisecting base $=2\cdot 40$;

4·11

2·40

1·375

3)7·885

2·628 mean breadth.

$2\cdot 628\times 5=13\cdot 14$,

and surface of both blades $=26\cdot 28$ sq. ft.

6. $11\cdot 5\times 104\times 60=71760$ feet, advance of screw per hour;

$\therefore \frac{71760}{6080}=11\cdot 8$, advance in knots per hour;

$\therefore$ 100 : 80·8 :: 11·8 : speed of ship.

Hence speed of ship $=\frac{11\cdot 8\times 80\cdot 8}{100}$

$=9\cdot 5$ knots.

7. The resistance against the paddles is so much increased, that the speed of the engine is considerably diminished; and consequently the difference between the diagram, taken under these circumstances, and what it would have been if the vessel were progressing through the water, is the same in kind as that between the latter diagram and the diagram obtained by throttling.

8. See *Indicator*, &c. p. 40.

9. Ditto. p. 50.

10. Ditto. p. 34.

11. Ditto. p. 44.

12. Ditto. pp. 22, 30.

No. 5. A.

1. See *Marine Engine*, art. 74.

2. Ditto ditto arts. 75 and 90.

3. Before the vacuum the effective pressure of steam is 15 lbs.

$\therefore$ force required to lift the valve $= 188 \cdot 496$ lbs.;

and after the partial vacuum,

pressure of steam $= 15 + 15$ lbs. $= 30$ lbs.

pressure in condenser $= 2$ lbs.;

$\therefore$ pressure per inch on valve $= 28$ lbs.

and area of valve $= \cdot 7854 \times 16$

$= 12 \cdot 5664$ square inches.

Force required to lift the valve $= 351 \cdot 86$ lbs.

4. See *Marine Engine*, art. 113, &c.

5. Ditto ditto arts. 108-111.

6. Let d = diameter of piston;

$\therefore \cdot 7854\, d^2 = 2376$;

$\therefore d = 55$ inches.

Hence diameter of piston $= \frac{55}{10} = 5\frac{1}{2}$ inches.

7. Let t=throw of the eccentric,
and l=length of valve-lifter;

$\therefore$ in the first case $\frac{t}{10}=\frac{12}{l}$

or $lt=120$.

Again, if x be the travel of the slide when the length of the gab-lever is 9 inches:

$$\frac{t}{9}=\frac{x}{l}$$

or $lt=9x$;

$\therefore 9x=120$,

or $x=\frac{120}{9}=13\frac{1}{3}$ inches.

8. See *Marine Engine*, arts. 134 and 136.

9. Force required $=\cdot 7854\ (11^2-10^2)\cdot 15$
$=\cdot 7854\times 21\times 15$
$=247\cdot 4$ lbs.

10. See *Marine Engine*, art. 170. The bottom of the cylinders in these engines forms the upper part of the condenser, and consequently the upper part of the condenser is always hot. This would have a tendency to cause incrustation.

11. Distance from end of side-lever to main center=9 feet,
distance from main center to connection of air-pump=$4\frac{1}{2}$ ft.;
$\therefore$ if force to lift the bucket be 3 cwt.
the pressure of steam to perform this=$1\frac{1}{2}$ cwt.
and hence the remaining force=20 cwt.$-1\frac{1}{2}$ cwt.=$18\frac{1}{2}$ cwt.

12. See *Marine Engine*, arts. 121 and 124.

13. Power of lever $=\frac{9}{2\frac{1}{2}}=\frac{18}{5}$

$\therefore$ pressure of weight on valve $=\frac{12\times 18}{5}$
$=43\cdot 2$ lbs.

Let p=pressure per inch;

$\therefore p\times\cdot 7854\times 2\cdot 5^2=43\cdot 2$;

$\therefore p=8\cdot 8$ lbs.

No. 5. B.

1. See *Marine Engine*, arts. 182 and 184.

2. Ditto ditto arts. 142, 189, and 190.

3. Horse-power of each engine $= \frac{90^2 \times 236}{6000}$

$= 318 \cdot 6$;

$\therefore$ horse-power of both engines $= 637 \cdot 2$.

Hence grate-surface required $= 637 \cdot 2$ square feet.

4. See *Marine Engine*, art. 207.

Let A = area of base of cylinder,

4 A = content of cylinder,

and weight of cylinder in lbs. $= \frac{525}{1728} \times 4$ A.

But if p = pressure per square inch,

p A = lifting-force on valve;

$\therefore p$ A $= \frac{525 \times 4}{1728}$ A,

or $p = \frac{2100}{1728} = 1 \cdot 21$ lbs.

5. The expansion-gear should not be used, because it might be necessary to reverse the engines; and this could not be done until the expansion-gear was thrown out.

6. Pressure per square inch $= (15 - 1) = 14$ lbs.

Hence total pressure $= \cdot 7854 \times 8 \cdot 5^2 \times 14$

$= \cdot 7854 \times 72 \cdot 25 \times 14$

$= 794 \cdot 4$ lbs.

7. See *Marine Engine*, art. 217. If a large quantity be kept in the boiler while under steam, the tubes are less likely to be uncovered, and there is less chance of accident.

8. See *Marine Engine*, art. 254.

9. Ditto ditto art. 265.

10. Ditto ditto art. 240.

11. See *Marine Engine*, art. 284.

12. Ditto ditto art. 317.

No. 5. C.

1. Horse-power of each engine $= \frac{(60^2 - 30^2)\,220}{6000}$

$= 99.$

Horse-power of both engines $= 198.$

2. Constant log. $= 5 \cdot 104909$ Log. $5 \cdot 333 = \cdot 726972$

Log. $2 \cdot 5 = 0 \cdot 397940$ Log. $5 \cdot 333 = \cdot 726972$

Log. Table E $= 0 \cdot 148911$ Log. $190 = 2 \cdot 278754$

$5 \cdot 651760$ $3 \cdot 732698$

$3 \cdot 732698$

$1 \cdot 919062$

Natural number $= 83 \cdot 000$ Log. $78 \cdot 773 = 1 \cdot 896370$

$4 \cdot 227 = 4 \cdot 227$ $0 \cdot 569982$

$78 \cdot 773$ Log. $21 \cdot 2$ lbs. $= 1 \cdot 326388$

3. The speed should be half as great again as the opposing current: therefore the rate should be 6 knots.

4. Let x be the consumption:

$$x : 3 :: 8^3 : 10^3$$

$$x = \frac{3 \times 8^3}{10^3} = 1 \cdot 53 \text{ tons.}$$

The dampers should be partially closed to check the draught.

5. Pitch of screw $= 3 \cdot 1416 \times 12 \times \tan. 18^\circ\ 40'$

Log. $3 \cdot 1416 = 0 \cdot 497206$

Log. $12 = 1 \cdot 079181$

Log. tan. $18^\circ 40' = 9 \cdot 528702$

$11 \cdot 105089$

10

Log. $12 \cdot 74 = 1 \cdot 105089$

$\therefore$ pitch $= 12 \cdot 74$ feet,

and length $= \frac{12 \cdot 74}{8} = 1 \cdot 59$ feet.

6. See *Indicator*, &c. p. 7.

7. Ditto. p. 7.

8. The lead is not observable in the ordinary diagram, because it takes place when the piston is stationary; but it may be exhibited by taking a continuous diagram.

9. See *Indicator*, &c. p. 21.

10.

ft.	in.	feet
10	9	$=10\frac{3}{4}=\frac{43}{4}$
3	6	$=3\frac{1}{2}=\frac{7}{2}$

$\therefore$ the pressure required $=\frac{\frac{7}{2}}{\frac{43}{4}}\times 45$

$=\frac{14}{43}\times 45$

$=14\cdot 6$ lbs.

11. See *Indicator*, &c. p. 50.

No. 6. A.

1. Area of each piston $=\frac{21000}{4}=5250$ square inches;

$\therefore$ diameter of each $=\sqrt{\frac{5250}{\cdot 7854}}=81\cdot 76$ inches.

2. See *Marine Engine*, art. 126.

Initial pressure $=\frac{3\text{ ,, }6}{2\text{ ,, }4}\times 14=\frac{3\frac{1}{2}}{2\frac{1}{3}}\times 14$

$=\frac{\frac{7}{2}}{\frac{7}{3}}\times 14=\frac{3}{2}\times 14=21$ lbs.

3. See *Marine Engine*, art. 129.

4. Ditto ditto art. 134.

(1) The mean pressure throughout the stroke is $7+12=19$ lbs.;

$\therefore$ the force in tons $=\frac{\cdot 7854\times 55^2\times 19}{2240}=$ tons. cwt. 20 3

(2) The mean pressure when not condensing $=7$ lbs. per inch;

$\therefore$ the force in tons $=\frac{\cdot 7854\times 55^2\times 7}{2240}=$ tons. cwt. 7 8.

5. Circumference of wheel $= 3 \cdot 1416 \times 9$;

$\therefore$ distance between boards $= \frac{3 \cdot 1416 \times 9}{15} =$ ft. in. 1 10.

6. See *Marine Engine*, arts. 158, &c.

7. The knots per hour advanced by screw

$$= \frac{16 \times 90 \times 60}{6080} = 14 \cdot 2,$$

and distance traversed by outer edge of screw

$$= \frac{3 \cdot 1416 \times 18 \times 90 \times 60}{6080}$$

$$= 50 \cdot 22 \text{ knots per hour.}$$

8. Let $d =$ diameter of the double-acting pump,
and $l =$ length of stroke.

Then, since its capacity must be half that of the single-acting pump (for it makes two strokes while the latter makes one),

$$\cdot 7854\ d^2 l = \tfrac{1}{2} \times \cdot 7854 \times 2^2 \times l;$$

$$\text{or } d^2 = \tfrac{1}{2} \times 4 = 2$$

$$d = \sqrt{2} = \sqrt{288} \text{ inches}$$

$$= 16 \cdot 9 \text{ inches.}$$

9. If the area of the feed-valve be 4 times that of the brine-valve, the diameter must be double; consequently, the diameter of the feed-valve being $4\frac{1}{2}$ inches, that of the brine-valve must be $2\frac{1}{4}$ inches.

10. If F be the force, and $\begin{cases} c = \text{length of crank,} \\ l = \text{length of stroke,} \end{cases}$

$$F \times 2\pi c = 4 \times 2l;$$

$$\therefore F = \frac{4l}{\pi c}$$

But $l = 2c$;

$$\therefore F = \frac{8}{\pi} = \frac{8}{3 \cdot 1416}$$

$$= 2 \cdot 5 \text{ tons.}$$

11. The water will lift the overflow-valve, and will either return to the hot-well, or escape overboard through the waste-water pipe.

12. The pressure of the steam will not be great enough to force the brine out of the blow-out cocks, and therefore the lower gauge-cocks should be opened, and a portion of the water allowed to escape into the bilge, from whence it may be ejected by the bilge-pumps.

No. 6. B.

1. Let d = diameter of the required cylinder;

$$\therefore 2 \times \cdot 7854 \times d^2 = \cdot 7854 \times 75^2;$$

$$\text{or } d^2 = \frac{75^2}{2}$$

$$d = \frac{75}{\sqrt{2}} = 53 \text{ inches.}$$

2. The sum of the two circumferences of the annular valve is the same as the circumference of the common valve.

Hence, if d be the inner diameter,

$$d + 16 = 20, \text{ or } d = 4.$$

3. The ice can be got rid of because it will in time become melted by the steam.

4. The pressure on a square inch at the depth of 24 feet will be found by the consideration that the pressure at the depth of 34 feet is the same as that of the atmosphere.

$\therefore$ if p be the pressure,

$$p : 24 :: 15 : 34;$$

$$\text{or } p = \frac{12}{17} \times 15 = \frac{180}{17} = 10 \cdot 5 \text{ lbs.}$$

Hence the pressure on the valve $= \cdot 7854 \times 6^2 \times 10 \cdot 5$

$$= 296 \cdot 88 \text{ lbs.}$$

5. See *Marine Engine*, art. 228.

6. Ditto ditto art. 237.

7. Let x = quantity blown out,

y = quantity evaporated in the same time,

$x + y$ = quantity admitted by feed;

$$\therefore \frac{4}{33}x = \frac{1}{33}(x + y),$$

$$\text{or } 4x = x + y,$$

$$3x = y,$$

$$x = \frac{y}{3};$$

or the quantity blown out must be $\frac{1}{3}$ that converted into steam.

8. See *Marine Engine*, art. 253.
9. Ditto ditto art. 259.
10. Ditto ditto art. 264.
11. Ditto ditto art. 304.
12. Ditto ditto art. 341.

No. 6. C.

1. See *Marine Engine*, pp. 300-302.

2. Nominal horse-power of each cylinder $= \frac{55^2 \times 5 \times 52}{6000}$

$$= \frac{786}{6} = 131;$$

$\therefore$ horse-power required $= 524$.

3. Const. log. $= 2 \cdot 747750$
$2 \times$ log. diam. $= 1 \cdot 321730$
Log. vel. $= 2 \cdot 484453$

Log. $3051000 = 6 \cdot 484453$

3051000
4323000 = horse-power of each $\times$ 33000
7374000

Log. $7374000 = 6 \cdot 867703$
$6 \cdot 510286$

Log. $2 \cdot 276 = \cdot 357417$

$\therefore$ evaporation required $= 2 \cdot 276 \times 4 = 9 \cdot 104$ cubic feet.

4. Speed of screw in feet per hour $= 7 \cdot 7 \times 40 \times 4 \times 60$

$$= 73920;$$

speed of ship in feet per hour $= 12 \times 6080 = 72960$;

$\therefore$ slip of screw $= \frac{73920 - 72960}{73920}$

$$= \frac{77 - 76}{77} = \frac{1}{77}$$

and slip per cent $= \frac{100}{77} = 1 \cdot 3$.

5. Let $x =$ the pitch required.

Speed of screw per hour in feet $= 30 \times 2 \cdot 5 \times 60 \times x$,

and speed of ship $= 10 \times 6080$;

$$\therefore \text{slip of screw} = \frac{30 \times 2 \cdot 5 \times 60x - 60800}{30 \times 2 \cdot 5 \times 60x} = \frac{25}{100} = \frac{1}{4}$$

$$\frac{45x - 608}{45x} = \frac{1}{4}$$

$$180x - 2432 = 45x$$

$$135x = 2432$$

$$x = \frac{2432}{135} = 18 \text{ feet.}$$

6. Since the horse-power varies as the cube of the speed,

$\therefore$ if x be the required power,

$$x : 250 :: 10 \cdot 5^3 : 9 \cdot 5^3;$$

$$\therefore x = \frac{10 \cdot 5^3 \times 250}{9 \cdot 5^3} = 337 \cdot 5.$$

7. Let OP = the crank = 3 feet (see Diagram, p. 99),

AP = the connecting-rod = 8 feet.

Now AB = 3, and OB = 8 − 3;

$\therefore$ AO = 8 feet.

$$\therefore \text{Cos. } \theta = \frac{\frac{OP}{2}}{AO} = \frac{3}{16}$$

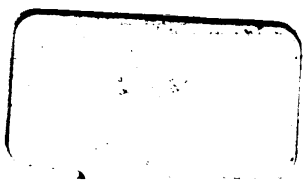
$\therefore \theta = 79° 11' 30''$ the angle required.

8. See *Indicator*, &c. pp. 7 and 18.

9. Ditto ditto pp. 31 and 50.

10. Ditto ditto p. 46.

11. Ditto ditto p. 30.



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